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(71) Applicant: TANTIVY COMMUNICATIONS, INC. [US/US]; 1450 S. Babcock Street, Melbourne, FL 32901 (US).

(72) Inventor: PROCTOR, James, A., Jr.; 258 Sea View Street, Melbourne, FL 32951 (US).

(74) Agents: THIBODEAU, David, J., Jr. et al.; Hamilton, Brook, Smith & Reynolds, P.C., 530 Virginia Road, P.O. Box 9133, Concord, MA 01742-9133 (US).

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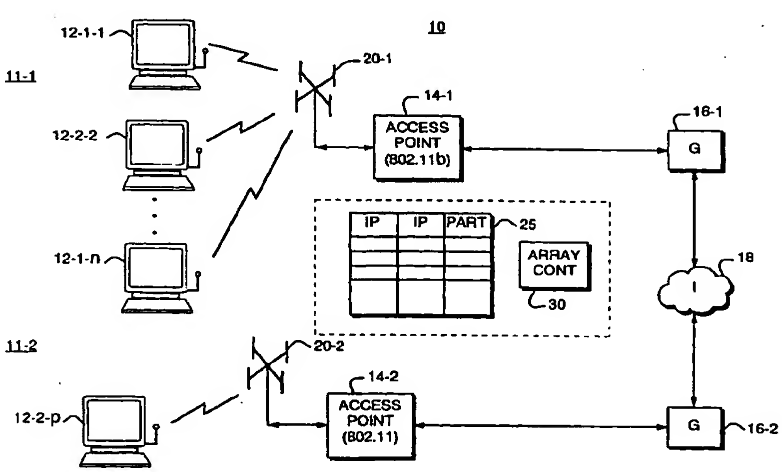
(54) Title: METHOD OF DETECTION OF SIGNALS USING AN ADAPTIVE ANTENNA IN A PEER-TO-PEER NETWORK



(57) Abstract: An adaptive antenna signal identification process to provide increased interference rejection in a wireless data network such as a wireless Local Area Network CLAN), The adaptive antenna is located at an access point and can be steered to various angle of arrival orientations with respect to received signals. Associated radio receiving equipment utilizes two distinct signal detection modes. In a first mode, the directional antenna array is set to have an omni-directional gain pattern. In this mode, certain identification parameters of an initial portion of a received signal are detected, such as a source identifier. If the received signal has not been previously detected, then the antenna array is scanned determine a direction setting that provides a best received signal metric. Once the best directional setting for the received signal, that setting is saved for future use in receiving the same signal. If the received signal has been previously detected, the system instead will steer the directional antenna to the last known best direction for reception for the particular detected signal. As further portions of the same signal are received, such as payload portions of a data frame, the directional antenna array can continue to scan potential new best angles. When the invention is deployed in a relay function, where messages received from a first node are to be forwarded to a second node, the recorded direction of its best reception is retrieved for the second node and used when the antenna array is used to transmit the signal to the second node. Storage of the best antenna angle for propagation to neighbor nodes can be handled by control functions in a manner that is analogous to other router lookup tables, such as being contained in a lookup table that stores IP addresses.

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METHOD OF DETECTION OF SIGNALS USING AN ADAPTIVE ANTENNA IN A PEER-TO-PEER NETWORK

BACKGROUND OF THE INVENTION

This invention relates generally to wireless data transmission systems and in particular to a technique for using directional antennas in such systems.

In corporate enterprises, wireless Local Area Networks (LANs) are usually implemented as a final link between existing wired networks and a group of client computers. Today's business environment is characterized by an increasingly mobile work force, who spend much of their time working in teams that cross functional, organizational and geographic boundaries. Often their most productive times occur in meetings that take place away from their desks. Users of portable computing equipment therefore need access to their data files through networks that reach far beyond their personal desktops. Wireless LANs fit well into this environment, providing much needed freedom in network access to mobile workers. Such networks provide access to information from anywhere within an enterprise, such as from a conference room, cafeteria, or even a remote branch office. Wireless LAN connectivity affords access to the full resources and services of a corporate network across a building or campus setting. As such, they are on the verge of becoming a mainstream solution for a broad range of business applications.

One critical issue affecting the effectiveness of wireless LAN deployment has been the historically limited throughput available with such equipment. The 2 Mega bits per second (Mbps) data rate specified by the original Institute of Electrical

and Electronics Engineers (IEEE) wireless LAN standard 802.11, dated 1997, is now considered to be too slow to support most business requirements. Recognizing the need to support additional higher data rate transmissions, the IEEE recently ratified an 802.11b standard that specifies data transmission speeds of up to 11 Mbps. With the 802.11b standard, wireless LANs are expected to be able to achieve throughput comparable to the legacy wired Ethernet infrastructure. Emerging wireless networking systems that promise to provide comparable data speeds include Home RF, BlueTooth, and third generation digital cellular telephone systems.

In these peer-to-peer networks, the individual computer nodes operate in a same frequency communication network. That is, these systems utilize signal modulation schemes such as Code Division Multiple Access (CDMA) wherein a number of end nodes are actually transmitting on a same radio frequency carrier at the same time. Such systems may experience significant quality degradation due to the interference of equipment that is not participating in system communication processes. For example, wireless LAN systems typically operate in unlicensed radio frequency bands. Other types of radio equipment operate in these bands, equipment that is not required to operate in accordance with the promulgated LAN standards, and therefore, cannot be controlled. These transmissions from such non-system nodes can significantly reduce the performance of a wireless LAN. As data rates increase, susceptibility to such interference also increases accordingly.

Various other problems are inherent in wireless communication systems. One such problem is the so-called multipath fading problem whereby a radio frequency signal transmitted from a sender (either a base station or another mobile subscriber unit) may encounter interference enroute to an intended receiver. The signal may, for example, be reflected from objects such as buildings that are not in a direct path of transmission but then are redirected as a reflected version of the original signal to the receiver. In such instances, the receiver actually receives two versions of the same radio signal: the original version and a reflected version. Since each received signal is at the same frequency but out of phase with one the other due the longer transmission path for the reflected signal, the original and reflected

signals may tend to cancel each other out. This results in dropouts or fading of the received signal.

Radio units that employ single element antennas are highly susceptible to such multipath fading. A single element antenna has no way of determining a direction from which a transmitted signal is sent and cannot be tuned or attenuated to more accurately detect or receive a signal in any particular direction operating by itself. It is known that directional antennas can therefore alleviate both the multipath fading and similar problems to some extent.

SUMMARY OF THE INVENTION

The present invention is used in a wireless data network that employs an adaptive directional antenna array to assist in isolating physical layer radio signals transmitted between system nodes. A controller can configure the antenna apparatus to maximize the affect of radiated and/or received energy. Specifically, the antenna apparatus typically includes multiple antenna elements and a like number of adjustable devices such as phase shifters, passive elements, or the like, that may be independently changed to effect the phase of received and/or transmitted signals. The antenna apparatus can therefore be oriented or steered to various angle of arrival orientations with respect to transmitted or received signals.

The adaptive antenna makes use of radio receiving equipment that utilizes two distinct signal detection modes. In a first receive mode, the controller sets the antenna to an omni-directional setting. This mode is used when a received signal has not yet been identified or the link layer connection established. A second receiver mode, in which the antenna is set to a specific directional angle, is used after a receive signal has been identified or a link layer connection established.

According to an embodiment of the invention that uses identification of the received signal to determine the antenna array mode, a multi-step process is employed.

In a first step of the process, the directional antenna array may be controlled such that it has an omni-directional gain pattern. In this mode, when an incoming

transmission is first received, certain identification parameters of an initial portion of the signal are detected. For example, these may be a source identifier encoded in a preamble portion of a Media Access Control (MAC) layer portion of a wireless Local Area Network (LAN) signal.

If the received signal has been previously detected, the controller will steer the directional antenna to a last known best direction for reception of further portions of the particular detected signal.

If the received signal has not been previously detected, then the controller scans the directional antenna to determine a direction setting that provides a best received signal metric. This can proceed, for example, as an angular search of possible antenna angle settings, and testing a received signal metric for each candidate direction. The received signal metric may, for example, be received signal strength, bit error rate, noise power, or other comparable measure. Once the best directional setting for the antenna is determined, that setting is saved for future use in receiving the identified signal.

As further portions of the same signal are received, such as payload portions of the data frame which follow a preamble portion, the directional antenna array can be operated to continue to scan potential new angles, continuing to look for the best signal metric in a directive mode all the time. Once a signal transmission is concluded, the last known best angle for that signal, along with an identification of the signal, for use in future reception of that same signal.

In a second embodiment, the invention also employs both the omni-directional and directional modes of the antenna, as in the previous embodiment. In a first step of this process, the antenna array is set to an omni-directional mode. A first portion of a received signal is then examined, to determine when a link layer establishment message, such as a Request to Send (RTS) message is received. After an RTS is detected, identification information for the sender of the RTS is used to determine a last known angle of arrival. The array is then steered to this direction for subsequent transmission of, for example, a Clear to Send (CTS) message. A follow-on step may be employed when an acknowledgement of the CTS is then

listened for; if the CTS acknowledgement is received, then it is known that the antenna is steered to a proper direction. However, if an acknowledgement of the CTS is not received, it is assumed that the antenna angle must be re-established through scanning candidate angles.

The foregoing embodiment is particularly useful in an access node or other central base unit.

Yet another embodiment of the invention can use the array as follows. An initial link layer transmission, such as a Request to Send (RTS) may be sent to an intended receiver in a directional mode. This embodiment is particularly useful where a sender has stored information as to a likely direction for the intended receiver. The unit then waits to receive a Clear to Send (CTS) indication in a receive mode with the antenna set to the same angle.

If the CTS is received, then it is assumed that the direction is correct, and a link layer connection is established.

However, if the CTS is not received within a specified time, the controller resets the array to an omni-directional mode, and attempts again to establish the link layer connection.

When the invention is deployed in a peer-to-peer network, it may also be used in connection with a device that is responsible for relaying messages from a first node to a second node. This functionality is an analogous to a router function in a wireline Internet Protocol (IP) network. In such an application, during the detection process, the angle providing the best received signal metric was recorded during the receive mode for a number of nodes in the networks as described above. Therefore, whenever a message is received from a first node that needs to be relayed to a second node, if signals have already been received from that second node, then the recorded direction of its best reception is retrieved and used when the antenna array is used to transmit the signal to the second node. Storage of the best antenna angle for propagation to neighbor nodes can be handled by control functions in a manner that is analogous to other router lookup table functions, such as being contained in a lookup table entry associated with IP addresses.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram of a system in which the invention is implemented.

Figs. 2A and 2B provide examples of Media Access Control (MAC) layer data frames or messages that may be used to format transmitted signals.

Fig. 3 is a sequence of steps performed by an antenna controller in order to process received signals according to a first embodiment.

Fig. 4 is a process diagram for the antenna controller according to a second embodiment.

Fig. 5 is yet another process which the controller may perform.

Fig. 6 illustrates a message and its acknowledgement.

Fig. 7 is a sequence of steps using acknowledgement suppression to confirm antenna angle setting.

Fig. 8 is a sequence of steps using contention-free periods to confirm antenna angle setting.

The foregoing and other objects, features and advantages of the invention will be apparent from the following more particular description of preferred embodiments of the invention, as illustrated in the accompanying drawings in which like reference characters refer to the same parts throughout the different views. The drawings are not necessarily to scale, emphasis instead being placed upon illustrating the principles of the invention.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

Fig. 1 is a high level block diagram of a wireless data communication network 10 in which the invention may be deployed, such as network for providing wireless connectivity between a number of end nodes 12 and a data network such as the Internet 18 through access point equipment 14.

Specifically, a first wireless Local Area Network (LAN) 11-1 formed by the nodes 12-1-1, 12-1-2, ... 12-1-n. These nodes 12-1 communicate with each other and a first access point 14-1 using specially formatted radio signals. A directional

antenna array 20-1 is used with the access point 14-1 in the first wireless LAN 11-1. The access point 14-1 is responsible for converting received radio frequency signals to their appropriate wired format such as the TCP/IP format suitable for Internet communications through a gateway 16-1. The gateway 16-1 may be a router, switch, or other internetworking device.

A similar second wireless LAN 11-2 involves the nodes 12-2-p, antenna 20-2, access point 14-2, and gateway 16-2.

Each of the nodes 12 include a remote station which is typically a portable Personal Computer (PC) equipped with a wireless network interface card (NIC). Other types of computing equipment such as Personal Digital Assistants (PDAs), desktop computing equipment, and other networkable devices are possible.

The access point (AP) 14-1 acts as a sort of bridge between the wireless network 10 and wired networks such as the Internet 18. The access point 14-1 acts as a base station for the physical layer signaling used in the wireless network, aggregating access for multiple wireless nodes 12-1-1, ... 12-1-n onto the wired network. The access point
14 usually consists of radio receiver and transmitter equipment and a wired network interface such as an IEEE 802.11 Ethernet interface. If the access point 14 is to provide connectivity to other networks, it may typically include bridging software conforming to, for example, 802.1 Bridging Standard, and other software such as firewalls and the like. It therefore acts as a router or bridge, from the perspective of higher layer data networking protocols.

In addition to standard wireless LAN signaling equipment, the access point 14-1 also contains a table 25 which is capable of storing identification information for the nodes 12 such as a unit identification and an associated antenna setting parameters, such as an angle. An array controller 30 that permits steering of the particular direction of the antenna 20-1 such as by specifying an angle. Signal receiving equipment in the access point 14-1 also contains detection circuits that are capable of determining a received signal metric, such as Received Signal Strength

Indication (RSSI), Bit Error Rate (BER), noise power level, or other such measures of receive signal quality..

Figs. 2A and 2B illustrate the format of a message or frame structure such as described in the wireless LAN specification IEEE 802.11b. The message consists of a Media Access Control (MAC) layer preamble, header, and payload portion or Protocol Specific Data Unit (PSDU). The messages in IEEE 802.11 may be either a long preamble-type as used in the connection with the message shown in Fig. 2A, as well as the short preamble-type as shown in Fig. 2B. The different frame formats are associated with supporting different data rates. The frame format shown in Fig. 2A uses either Double Binary Phase Shift Keying (DBPSK) or Double Quadrature Phase Shift Keying (DQPSK) encoded at, respectively, 1 Mbps or 2 Mbps to modulate the payload portion. The frame format in Fig. 2B utilizes DQPSK to realize data rates of 5.5 Mbps or 11 Mbps.

Note also that for both frame formats, the preamble and header portions of the frame utilize a more robust encoding scheme than the data payload portions. This permits more reliable detection of the header and preamble in the presence of noise.

The preamble of either formats shown in Fig. 2A or 2B include an indication of the particular senders, such as in the SFD portion.

Fig. 3 illustrates a flow chart of a process for receiving wireless network signals in accordance with the invention. The process is performed in an access point 14 as it receives signals from nodes 12, and may typically be carried out during physical layer processing.

From a first idle step 300, the antenna 20 associated with the respective access point 14 is initially set into an omni-directional mode. In this omni-directional mode, a state 320 is then entered in which the preamble portion and/or header of a received signal is detected. In state 330, the initial portion of the received signal is examined to identify it uniquely. If the received signal is unknown, e.g., the node 12 which originated the signal has not been seen before, the antenna is then set in an angle search mode in state 322. In this mode, the antenna

20 is therefore stepped through a sequence of directional angles to find a direction of maximum received signal strength, signal quality, lowest Bit Error Rate (BER) or other signal quality metric. In state 323, when this angle is determined, it is recorded and associated with the device identification information, such as a table entry 25 associated with that device. The table as shown in Fig. 1 may be kept by the access point 14 as part of its message routing table.

In any event, the access point 14 may then enter a state 324 in which during active receptions, the optimum angle is continuously adjusted while receiving the payload data portion of the frame. If reception of the frame is then lost or otherwise completed, then the last best known angle is recoded in the table, and processing returns to the initial state 310.

If from state 330 the signal was able to be identified, e.g., a signal has been previously received from the transmitting node 12, then processing proceeds to a state 325 in which the last known angle is looked up in the table 25. This last known angle is then used by the controller 30 to steer the array to the last known position. The array then remains in this last known position at least for reception of the payload portion of the signal in state 326. From there, the state 324 may continue to be entered as the payload portion is being received whereby the angle is continuously adjusted while it is active and any updates are then recorded in the table 25.

The state 328 may be entered from state 326 if the unit is in a relay mode, where the best received angle may be used a subsequent transmissions to that same node.

Fig. 4 is a diagram of a slightly modified process that may also be used according to the present invention. The number of steps of the process in Fig. 4 correspond, more or less, to the steps of Fig. 3. For example, from a first idle step 300, the antenna 20 is initially set in step 310 to an omni-directional mode. However, in this embodiment higher layer level signaling is examined. For example, in step 315, a Request to Send (RTS) message is detected such as at a link layer. In step 330, the message is again examined to see if the originator has a known identification. If so, steps 325 and 326 proceed as previously where the last

known angle associated with that sender is determined in step 325 and the antenna 20 is steered to the last known angle in step 326. In this instance, the unit will then send a Clear to Send (CTS) message in step 340 with the antenna now set to the last known angle.

If however, back in step 330, if the identification of the detected RTS is not known, then an angle search proceeds in state 322 and the ID and angle of the best reception state is recorded in step 323. Step 324 continues as previously where the angle may be adjusted while active payload data is being received. Step 345 may be entered when the signal detection is lost and/or an end of message (EOM) is received.

Returning attention to an instance in which the last known angle is steered to in state 326, a Clear to Send (CTS) message is sent step 340. Next, a CTS acknowledgement is waited for in step 342. The acknowledgement would typically be received within a predetermined amount of time or otherwise a time-out condition exists. If the acknowledgement is received, then the specified angle is presumed to be okay and in state 344 and then processing may proceed to step 324. However, if a time-out does occur in step 342, then it is presumed that the angle to which the antenna 20 was steered is bad and therefore the angle search state 322 must be entered.

The foregoing methods are particularly useful in applying an application to an access node or central base station unit wherein it is intended to service a number of remote subscriber units.

However, another embodiment of the invention can be applied to advantage in a subscriber unit as follows. This set of operations is illustrated in Fig. 5. In a first step 500, the antenna is set to a directional mode. For example, it is typically common that the subscriber will have the given information with respect to its candidate direction in which the base station exists. In step 510, a Request to Send (RTS) message is sent in a directional mode. In step 520, if a Clear to Send (CTS) message is received back from the base station, then it can be presumed that the

antenna direction setting is okay in step 522 and the link layer communications may proceed in step 524.

If however, in step 520 there is no CTS received within a time-out period, then it is presumed that the antenna is incorrectly set. Thus, an omni-directional mode is entered in step 528 and the RTS message is sent in step 540. Processing then proceeds from that point similar to that described in Fig. 3 and/or Fig. 4, i.e., an angle search is performed to properly set the antenna in step 544 and the setting is recorded in step 548.

Fig. 5 illustrates a sequence of higher level messages that may be sent in a typical network computer environment. Specifically, a source station which may either be the access point 14-1 or remote stations 12, sends a message 610. The message 610 may consist of one or more packets that have the previously described preamble, header, and payload portions. The message may be a relatively detailed message or may be a relatively simple message such as a request to set up a connection and send further information.

In response to receipt of the message 610, the destination station is expected to return and acknowledgement message 612. This acknowledgement message 612 may have a preamble portion and a header portion that specifically has a header or payload portion that is a known acknowledgement (ACK) format. The higher layer protocol may be, for example, implemented at a link layer.

The present invention may make use of these higher layer protocol units to invoke other protocols to help train the antenna.

The acknowledgement message 612 is sent upon receipt of a proper message 610 at the destination station. However, situations may also exit 614 in which no acknowledgement is sent from the destination. This is typically done if the message is not received within a predetermined period of time at the destination. In that manner, the source will know to attempt to retransmit the message 610. This acknowledgement protocol is typical of higher layer protocols in widespread usage in data communication networks typical of the Transmission Control Protocol/Internet Protocol (TCP/IP) protocol used in Internet data communications.

It may become necessary to use the higher layer protocol information in certain circumstances wherein the physical layer protocols do not permit time to demodulate the data frame and/or do not contain identification of the sending station in the preamble portion. Such protocols present a problem in that there is no way to know transmitter ends without some type of demodulation taking place. However, there is, in turn, no time in which to or there is no time in which to demodulate the signal. For example, it may not be possible to determine quality of a reception until after an entire frame is processed. This may depend upon the specific coding used for the frame. In addition, certain protocols may use preamble portions that are too short in duration to identify the best direction in time for this antenna array to be affectively steered to the appropriate direction. For example, 802.11B Standard is potentially acceptable in this regard. However, protocols such as the 802.11A Wireless LAN Standard may not provide sufficient duration preamble. In addition, the wireless LAN protocols work on a similar radio link protocol that is similar to Ethernet. In particular, a positive acknowledgement radio link protocol is used. For example, if correctly received packets are acknowledged whereas incorrectly received packets are not. Thus, the non-acknowledgement test can be performed at a radio link protocol layer and/or higher level layers.

Essentially, the process is shown as in Fig. 6. For an initial idle state 600, tenant array 20 is first steered to an omni-directional state.

In a next state 712, a transmission is received. When this packet is received correctly, a state 714 is entered in which the acknowledgement 612 that would normally be sent is suppressed. Therefore, the unit enters a mode in which no acknowledgement is sent 614. This permits entry to a state 716 in which the angle for the antenna may be set. The suppression of the acknowledgement in state 714 causes a second receipt of the packet in state 718. In this second receipt in state 720, the received quality is compared. If the received quality is not adequate, then the process loops back to state 714 in which the acknowledgement is suppressed once again. Step 714 through 720 are continuously executed until an acceptable received packet quality is determined in state 720. When this occurs, control passes to state

722 in which an acknowledgement is presently sent. The set angle is then recorded with the identification of the unit for subsequent communication with that unit.

It should be understood that in certain instances upon receipt of the packet in 712, if the identification of the unit can be determined, then the angle may be more appropriately set upon the second try in state 716, such as in shown in Fig. 3. For example, if the identification of the remote unit can be made from the received packet in state 712, then the angle search associated with step 714 through 720 can proceed more expeditiously.

What is important to note here is that the higher layer protocol is being used to force a retransmission of a packet for the purpose of optimizing the antenna array setting. Other protocol attributes or units could be used for similar results. For example, a contention-free window can be set up by certain protocols using a so-called PCF or HCF mode. In the PCF mode, a means is provided for discovering the best angle that can be controlled by an access point as to which units will be transmitting during a certain period of time. Thus, the identification of the unit being known in advance, the antenna can be steered to the last known direction for the communication prior to its receipt. Thus, the control messages may be set up while an omni-directional mode then when transmitting to the remote unit, the directed mode can in HCF or Hybrid Coordination Function can be determined.

Turning attention more particularly to Fig. 8, an 802.11 access point 12 has essentially two modes, including a distributed correlation function (DCF) mode 810 and a point coordination function (PCF) mode 830. In the DCF mode, communication is basically contention-based whereby any one of the subscriber units 12 may be allowed to attempt to send messages to the access point 14 at any point in time. The PCF mode 830 is entered into from time to time to provide a mode in which contention-free communication is possible. Thus, while in the PCF mode, the system guarantees to a particular subscriber unit 12 that it will be able to have exclusive access to the airwaves and send messages to the access point 814, free of any collision with other subscriber units 12.

Thus, in one state 812 associated with DCF mode 810, the access point 14 receives requests on a sporadic basis from particular subscriber units 12 to be granted contention-free areas (CF) at a later time. Eventually, the PCF mode is entered in state 830. In this state, the antenna is first sent to an omni-directional mode 832. In a next state 834, a beacon signal is sent to all subscriber units 12 to indicate that the PCF mode is being entered into. This is a signal to all units to listen for upcoming polling information to determine if they will be granted a contention-free period. A poll signal is then sent out at state 834. A response to the poll signal in state 834 determines a particular identifier of one of the subscriber units 12 which is to be granted contention-free access during the PCF mode. It should be understood that during any given PCF mode, a number of different subscriber units 12 may be granted exclusive use or may be granted a contention-free period one after the other.

From its schedule of subscriber units 12 that have requested contention-free periods, the access point in state 834 polls the first such unit on its list. The poll message is sent by steering the antenna to the last known location or correct angle for the particular identified subscriber unit 12. This particular PCF message is then sent in step 838 as a contention-free message. Steps 834 through 838 are then continuously executed until each of the subscriber units that had requested a CF eventually be granted their turn at a contention-free period. Upon each subsequent such subscriber unit 12 being accessed during the contention-free period, the antenna will be steered to its respective appropriate direction in the state 836 prior to sending the associated PCF message for the particular subscriber unit 12. At the end of the contention-free processing in state 838, the access unit may then steer the antenna array 20 back to an omni-directional mode so that in a state 840, a contention-free period end message may be sent to all of the subscriber units so that they may understand that the end of PCF mode has been reached and that the system is then now returning to a DCF mode in state 810.

While this invention has been particularly shown and described with references to preferred embodiments thereof, it will be understood by those skilled in

the art that various changes in form and details may be made therein without departing from the scope of the invention encompassed by the appended claims.

CLAIMS

What is claimed is:

1. A method for operating a wireless data communication system in which a first station communicates with a second station using a wireless physical layer signaling protocol, and the first station making use of a directional antenna, the method comprising the steps of:

determining when a wireless signal containing a data packet is being received by the first station;

determining an identification of a transmitting second station that transmitted the wireless signal to the first station from a first portion of the transmission from the second station;

using the determined identification of the second station to determine parameters for the directional antenna array; and

during reception of a subsequent portion of the signal transmission from the second station, steering the directional antenna according to the parameters for the identified second station.

2. A method as in claim 1 wherein the first station is an access point, and the second station is a remote station.

3. A method as in claim 1 wherein the first station is a remote station and the second station is an access point.

4. A method as in claim 1 wherein the first received portion is a preamble of a frame.

5. A method as in claim 1 wherein the first portion of the received signal is a first packet in a series of packets.

6. A method as in claim 1 wherein the subsequent transmission is a later portion of the frame.

7. A method as in claim 1 wherein the subsequent transmission is a later frame in a series of transmitted frames.

8. A method as in claim 1 wherein the directional antenna is a steerable array of multiple antenna elements.

9. A method as in claim 4 wherein the preamble portion of the data frame is encoded with a more robust modulation scheme than the following portions of the transmission.

10. A method as in claim 4 wherein the preamble portion may have one of a plurality of possible preamble formats.

11. A method as in claim 4 wherein the preamble portion contains sender identification and the payload is regarded as subsequently sent frames.

12. A method as in claim 1 wherein antenna array parameters are associated with the identification of the second station.

13. A method as in claim 13 wherein the unit identification and antenna parameters are stored in a table associated with a network layer address associated with forwarding communications between the first and second station.

14. A method as in claim 13 wherein the network address is an Internet Protocol address and the first station performs routing functions for network layer messaging.

15. A method as in claim 1 additionally comprising the step of:

if it is not possible to determine an identification of antenna parameters from the identification of the second station,

searching for an antenna parameter setting to determine an optimum direction for receipt of communications from the second station.

16. A method as in claim 1 wherein the step of determining an identification of the transmitting second station occurs from a portion of the communication received while the antenna is operating in an omni-directional mode.

17. A method as in claim 1 wherein a robust, lower coded modulation type is used during transmission of a first portion, and a higher coded modulation type is used during a later portion of the transmission from the second station.

18. A method as in claim 17 wherein the identification information is located in the higher coded portion of the transmission.

19. A method as in claim 17 wherein the directional antenna is steered to the last known direction before later portions of the transmission are received.

20. A method as in claim 19 wherein the later portions of the transmission may also be subsequently transmitted data frames.

21. A method as in claim 7 additionally comprising the step of:

if identification of the transmitting second station is unknown, steering the directional antenna to determine an optimum direction for receipt of communications.

22. A method as in claim 21 wherein the identification is determined after the reception of a first frame.

23. A method as in claim 8 additionally comprising the step of:

after the optimum direction is determined, storing the direction information, together with the unit identification information, for use in subsequent processing of signals received from the identified unit.

24. A method as in claim 1 additionally comprising the step of:

sending a Clear to Send (CTS) indication from the first station to the second station;

listening for receipt of an acknowledgement of the Clear to Send signal;

if such acknowledgement is received, determining that the present setting of the directional antenna is sufficient; and

if the acknowledgement is not received, then determining a different angle for the transmission.

25. A method for operating a communication network in which a first station communicates with a second station using wireless physical layer signaling and comprising the steps of:

setting an omni-directional mode for an antenna array;

receiving transmissions at the first station from the second station;

determining an identification of the second station from the received transmission; and

steering the directional antenna array in the direction of the last known location for the identified unit.

26. A method as in claim 25 wherein the first station is an access point and the second station is a remote station.

27. A method as in claim 25 wherein the first station is a remote station and the second station is an access point.

28. A method as in claim 25 wherein the first portion of the transmission is a preamble of a data frame.

29. A method as in claim 25 wherein the first portion of the transmission is a first packet.

30. A method as in claim 25 wherein a subsequent transmission is a later portion of a data frame.

31. A method as in claim 25 wherein a subsequent transmission is a later transmitted packet.

32. A method as in claim 28 wherein the preamble portion is a complete data frame containing identification of a sender.

33. A method as in claim 25 wherein the step of determining identification of the transmitting second station occurs from a portion of the transmission received while the antenna is operating in the omni-directional mode.

34. A method as in claim 33 wherein identification is contained in a higher coded portion of the transmission.

35. A method as in claim 25 wherein the directional antenna is steered to the last known direction before later portions of the transmission begin.

36. A method as in claim 25 additionally comprising the step of:

if identification of the second station is not determined, steering the directional antenna through a series of candidate directions to determine an optimum direction for receipt of communications from the transmitting unit.

37. A method as in claim 36 additionally comprising the step of:

after the optimum direction is determined, storing the direction information, together with the unit identification information, for use in subsequent processing of signals received from the identified unit.

38. A method as in claim 5 additionally comprising the step of:

during a sequence of known series of transferred packets, steering the antenna array without concern for packet loss.

39. A method as in claim 38 additionally comprising the step of:

employing a packet acknowledgement mechanism to recover any lost data.

40. A method as in claim 38 additionally comprising the step of:

relying on a radio link control protocol (RLP) mechanism to recover lost packets.

41. A method of operating a communication system in which a first and second station exchanges information, the communication occurring using wireless physical layer signaling, and the first station making use of a directional antenna, the method comprising the steps of:

determining when a wireless signal is being received from the second station at the first station;

utilizing messages at a protocol layer higher than the physical layer to control transmission and retransmission of data from a specific second station; and

using the transmitted messages at higher layer protocols to steer the antenna array.

42. A method as in claim 41 wherein the protocol attributes are used to force a retransmission of the data packet for the purpose of optimizing the antenna array steering.

43. A method as in claim 42 wherein the protocol attribute is an acknowledgement (ACK) returned from the first station to the second station.

44. A method as in claim 43 wherein the acknowledgement message is suppressed in order to force a retransmission from the second station to the first station.

45. A method as in claim 44 wherein the acknowledgment suppression is performed only upon one of a number, N, of transmissions to provide for reduction in duty cycle of the adaptation of the antenna.

46. A method as in claim 43 additionally comprising the step of:

after the first acknowledgement suppression, identifying the second station from which the transmission is being received to determine an angle for the antenna based upon the history of past transmissions from the specific second station.

47. A method as in claim 41 wherein the protocol units utilize Request to Send (RTS) and Clear to Send (CTS) protocol data units to ensure transmission of frames from a specific second station.

48. A method as in claim 41 wherein the protocol units are Point Coordination Function (PCF) entities that only request a specific second station to transmit.

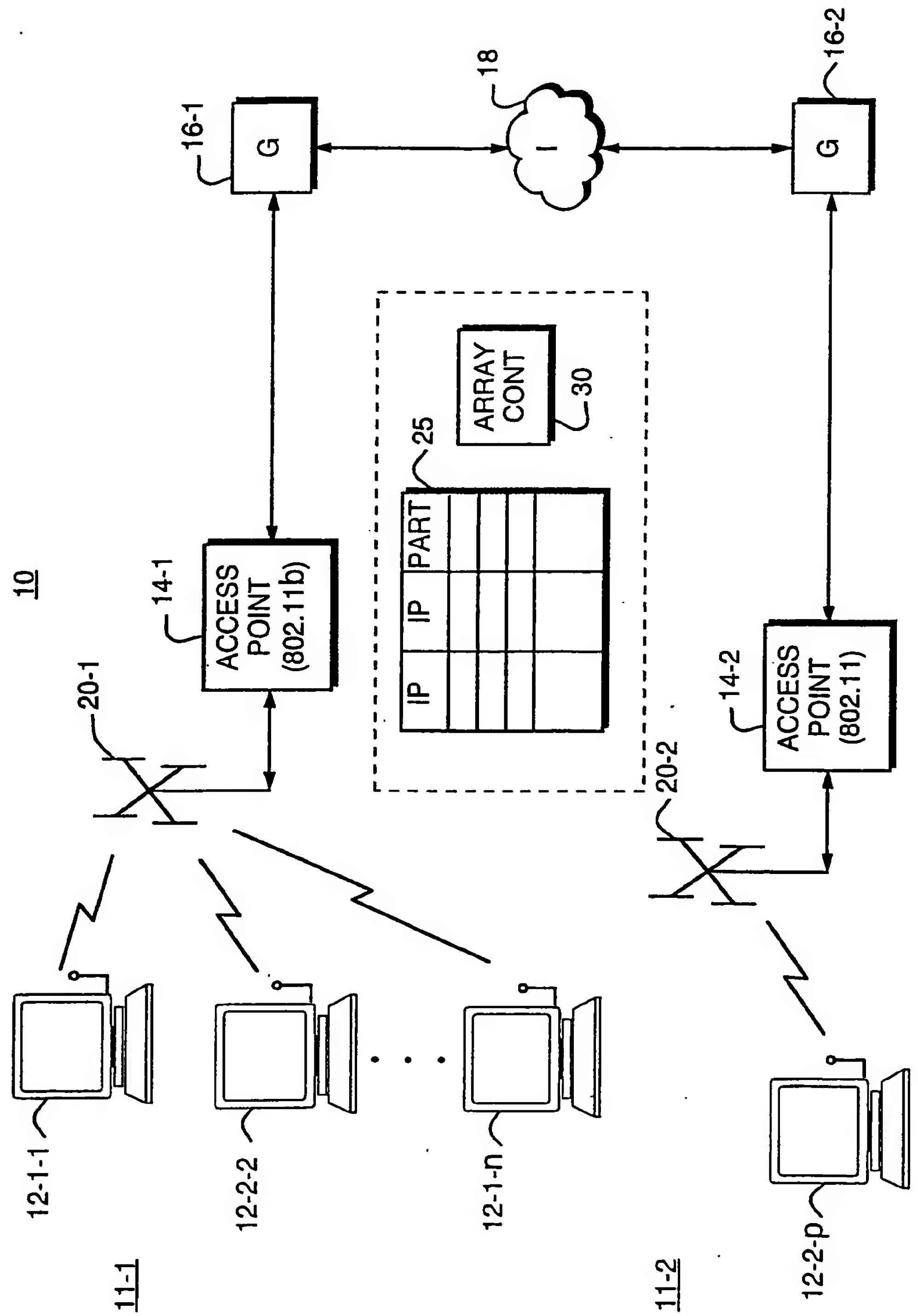
10
11-1
11-2
12-1-1
12-2-2
12-1-n
12-2-p
20-1
20-2
14-1
ACCESS POINT (802.11b)
14-2
ACCESS POINT (802.11)
16-1
G
16-2
G
18
I
25
IP
IP
PART
ARRAY CONT
30

FIG. 1

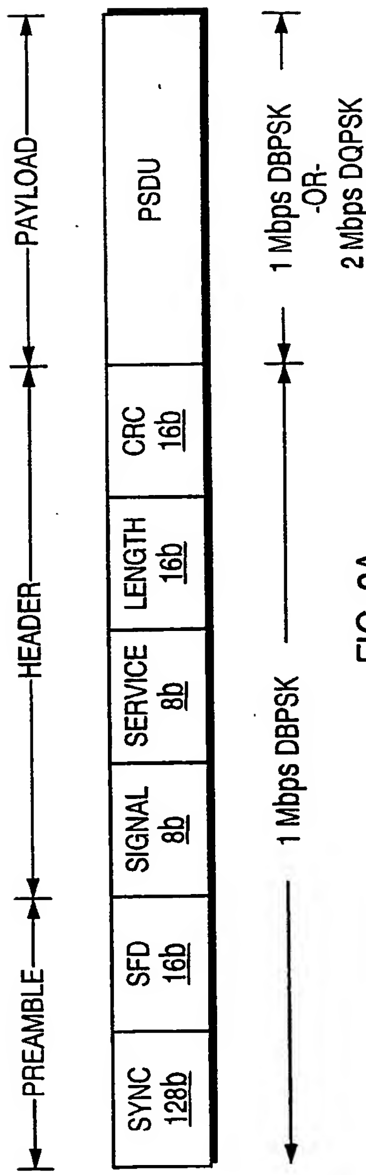
PREAMBLE
HEADER
PAYLOAD
SYNC
128b
SFD
16b
SIGNAL
8b
SERVICE
8b
LENGTH
16b
CRC
16b
PSDU
1 Mbps DBPSK
1 Mbps DBPSK
-OR-
2 Mbps DQPSK

FIG. 2A

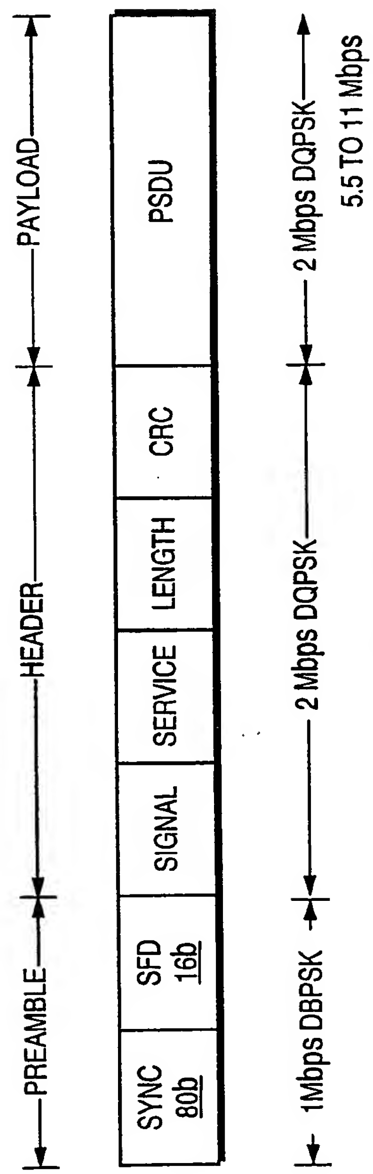
PREAMBLE
HEADER
PAYLOAD
SYNC
80b
SFD
16b
SIGNAL
SERVICE
LENGTH
CRC
PSDU
1Mbps DBPSK
2 Mbps DQPSK
2 Mbps DQPSK
5.5 TO 11 Mbps

FIG. 2B

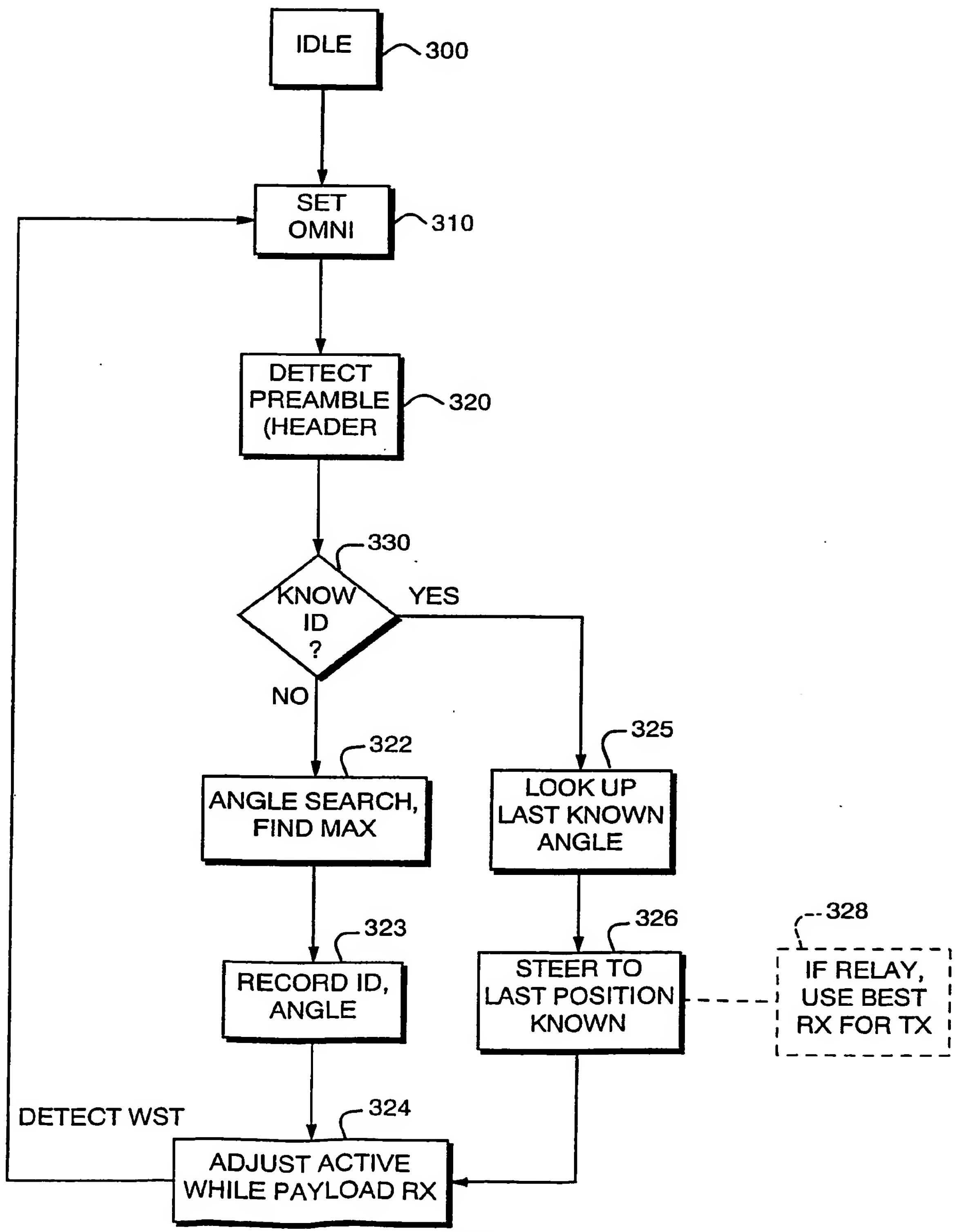
IDLE
300
SET OMNI
310
DETECT PREAMBLE (HEADER
320
330
KNOW ID ?
YES
NO
322
ANGLE SEARCH, FIND MAX
325
LOOK UP LAST KNOWN ANGLE
323
RECORD ID, ANGLE
326
STEER TO LAST POSITION KNOWN
328
IF RELAY, USE BEST RX FOR TX
DETECT WST
324
ADJUST ACTIVE WHILE PAYLOAD RX

FIG. 3

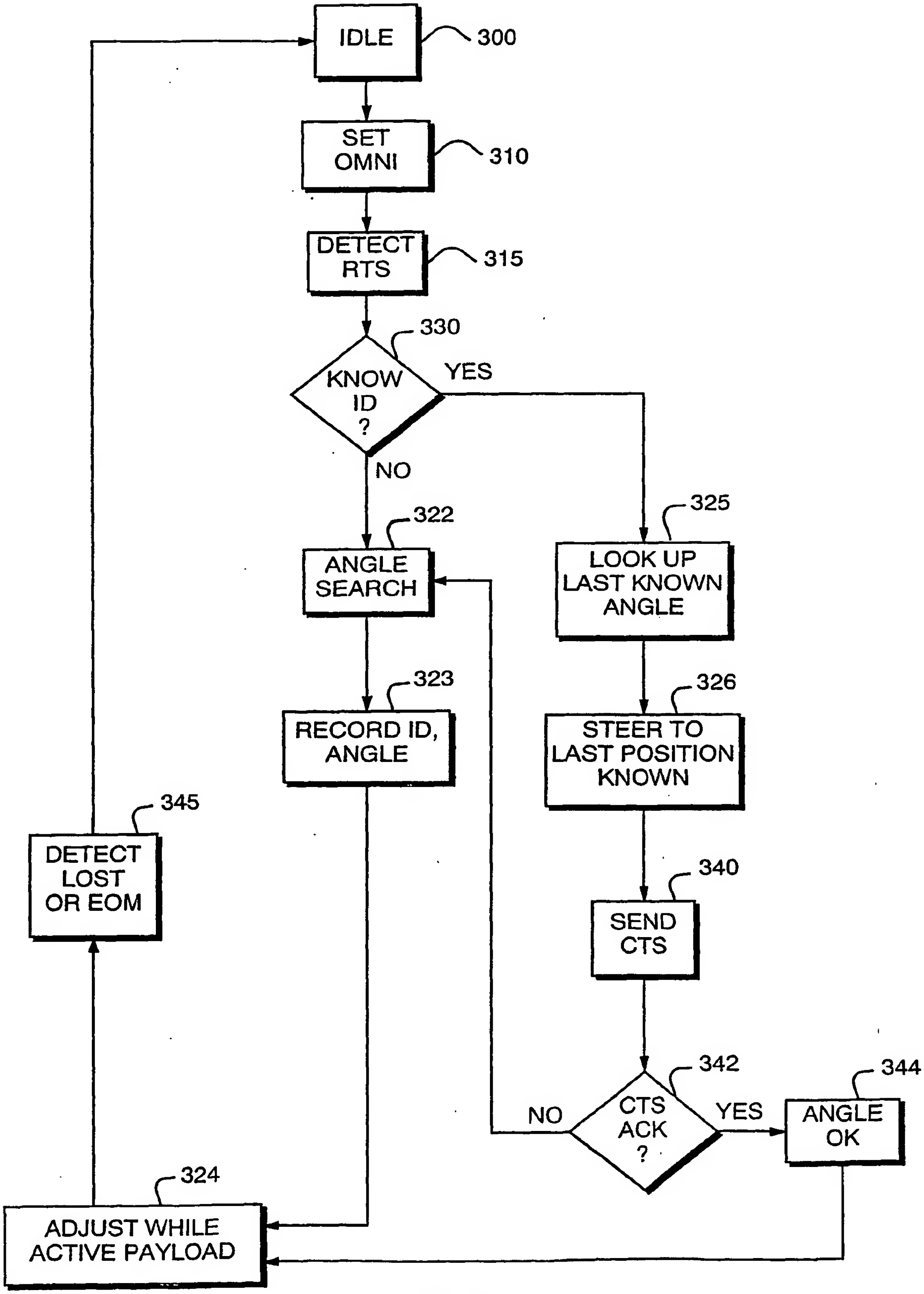
IDLE
300
SET OMNI
310
DETECT RTS
315
330
KNOW ID ?
YES
NO
322
ANGLE SEARCH
325
LOOK UP LAST KNOWN ANGLE
323
RECORD ID, ANGLE
326
STEER TO LAST POSITION KNOWN
345
DETECT LOST OR EOM
340
SEND CTS
342
CTS ACK ?
NO
YES
344
ANGLE OK
324
ADJUST WHILE ACTIVE PAYLOAD

FIG. 4

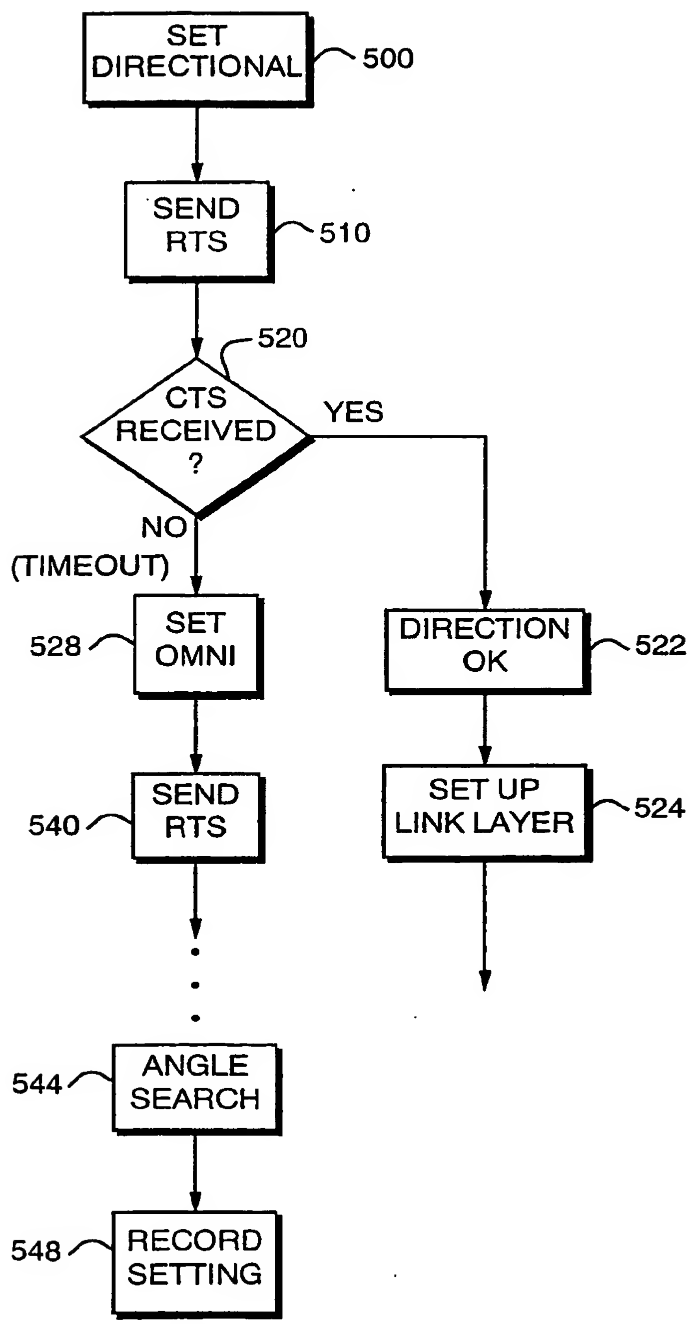
SET DIRECTIONAL
500
SEND RTS
510
520
CTS RECEIVED ?
YES
NO (TIMEOUT)
SET OMNI
528
DIRECTION OK
522
SEND RTS
540
SET UP LINK LAYER
524
ANGLE SEARCH
544
RECORD SETTING
548

FIG. 5

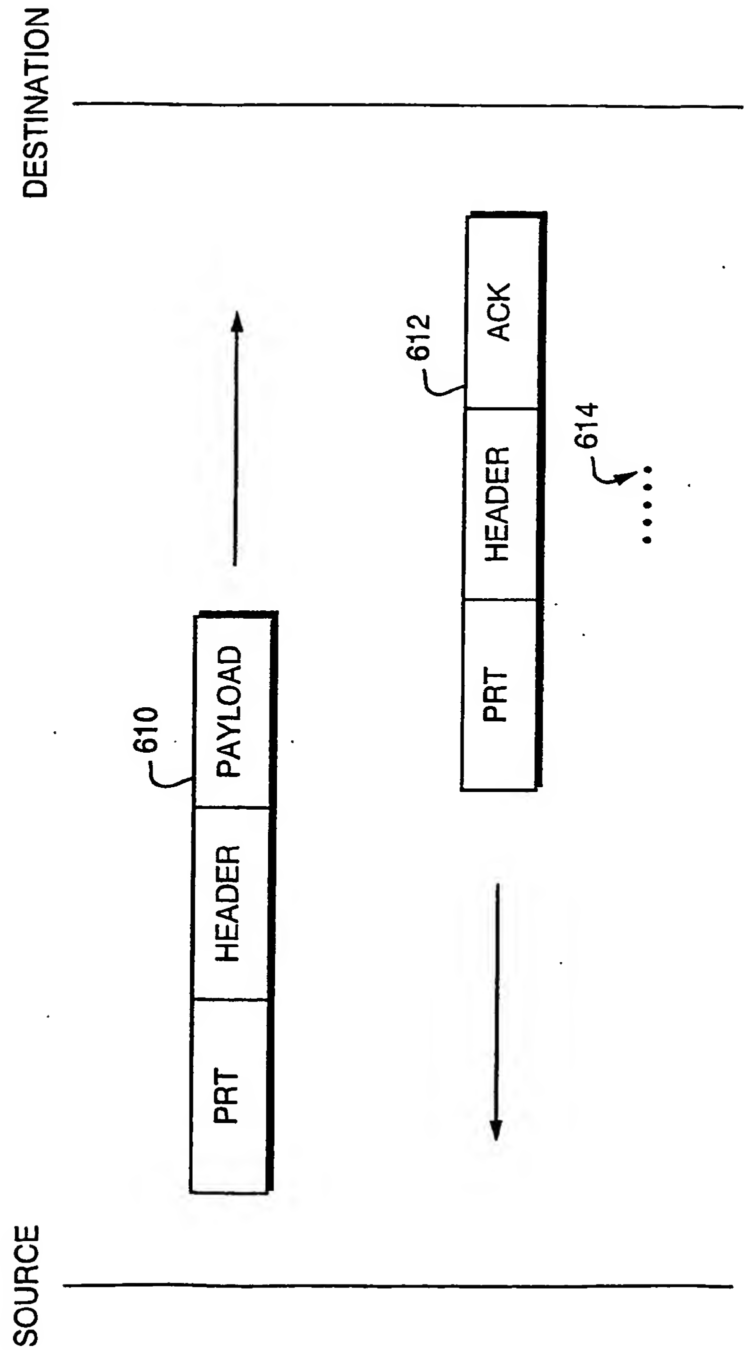
DESTINATION
ACK
612
HEADER
PRT
614
PAYLOAD
610
HEADER
PRT
SOURCE

FIG. 6

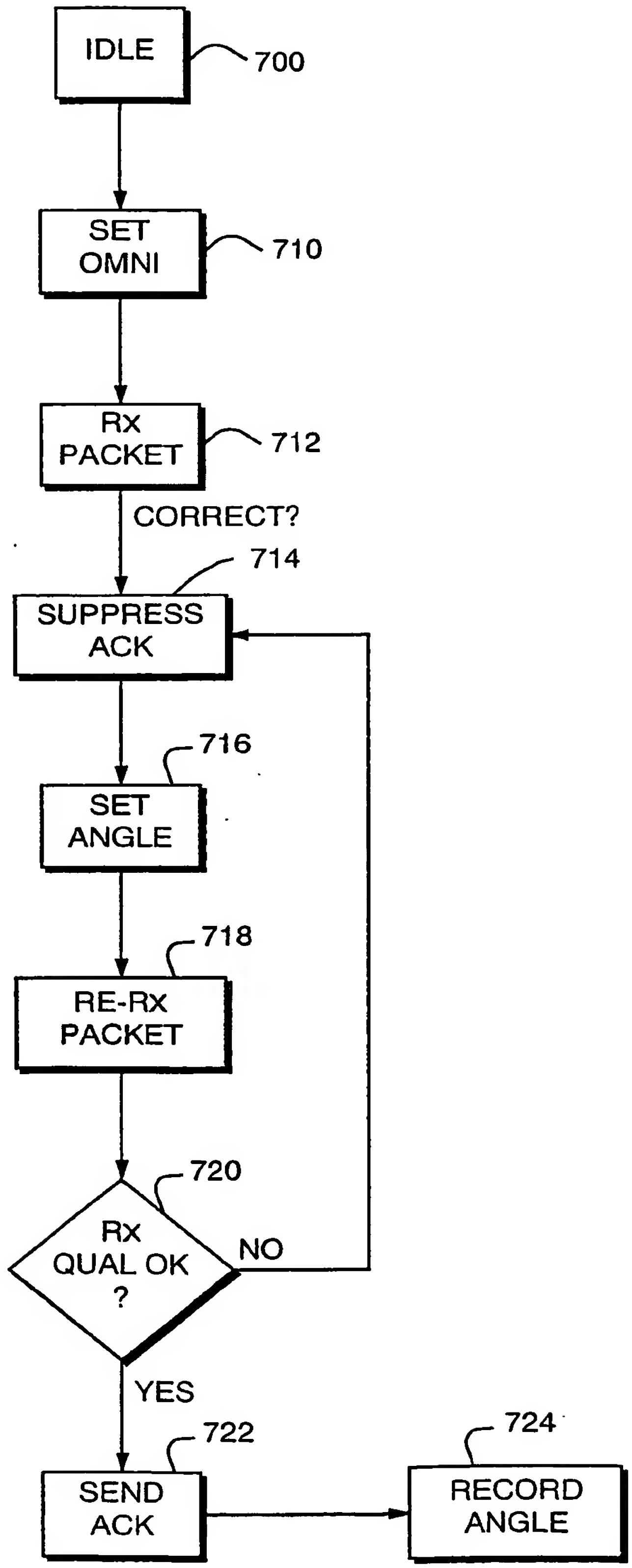
IDLE
700
SET OMNI
710
Rx PACKET
712
CORRECT?
714
SUPPRESS ACK
716
SET ANGLE
718
RE-Rx PACKET
720
Rx QUAL OK ?
NO
YES
722
SEND ACK
724
RECORD ANGLE

FIG. 7

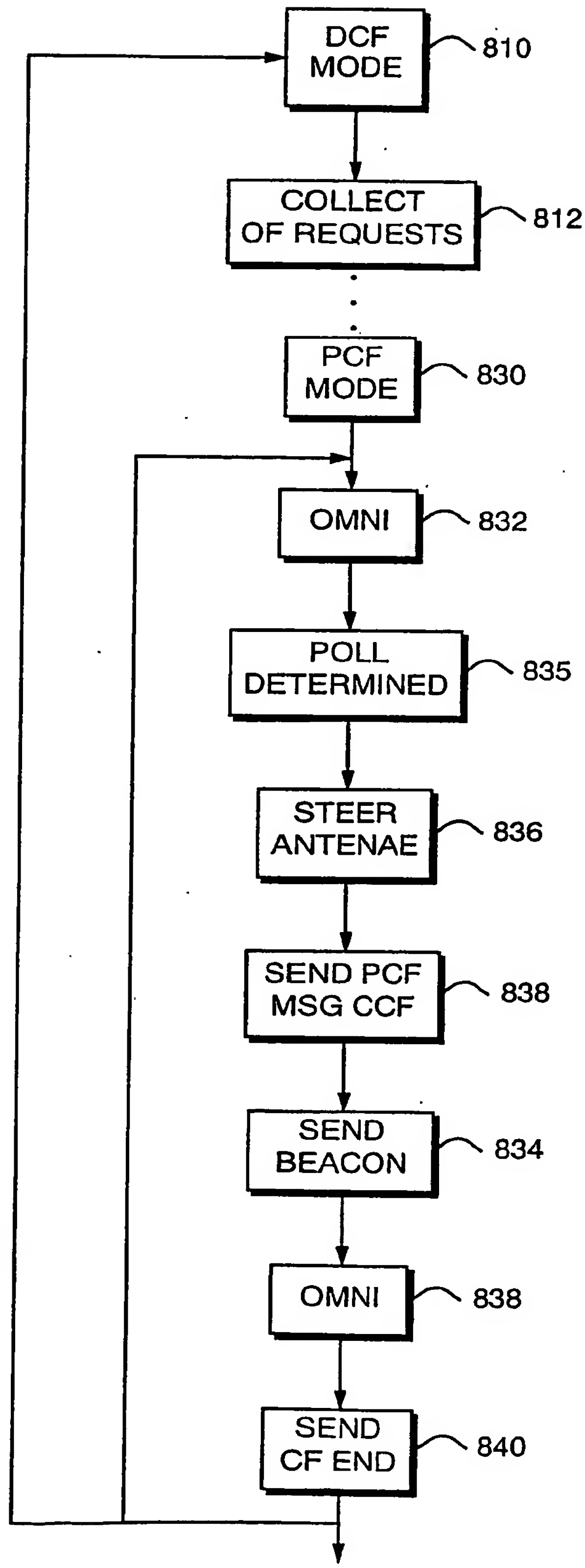
DCF MODE
810
COLLECT OF REQUESTS
812
PCF MODE
830
OMNI
832
POLL DETERMINED
835
STEER ANTENAE
836
SEND PCF MSG CCF
838
SEND BEACON
834
OMNI
838
SEND CF END
840

FIG. 8

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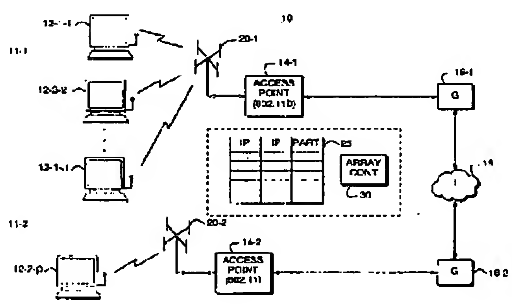
(21) 出願番号　特願2003-527831 (P2003-527831)	(71) 出願人　500552216
(86) (22) 出願日　平成14年9月12日 (2002.9.12)	タンティビ・コミュニケーションズ・インコーポレーテッド
(85) 翻訳文提出日　平成16年3月12日 (2004.3.12)	TANTIVY COMMUNICATIONS, INC.
(86) 国際出願番号　PCT/US2002/029147	アメリカ合衆国, フロリダ州　32901, メルボルン, サウス　バブコック　ストリート　1450
(87) 国際公開番号　WO2003/023895	(74) 代理人　100087941 弁理士　杉本　修司
(87) 国際公開日　平成15年3月20日 (2003.3.20)	(74) 代理人　100086793 弁理士　野田　雅士
(31) 優先権主張番号　09/952,198	(74) 代理人　100112829 弁理士　堤　健郎
(32) 優先日　平成13年9月13日 (2001.9.13)	
(33) 優先権主張国　米国 (US)	

最終頁に続く

(54)【発明の名称】ピアツーピア・ネットワークにおけるアダプティブ・アンテナを用いる信号検出方法

(57)【要約】
無線ＬＡＮ（ローカル・エリア・ネットワーク）（１１－１、１１－２）のような無線データ・ネットワークにおいて、優れた干渉阻止性能を提供するアダプティブ・アンテナ信号識別方法が提供される。アダプティブ・アンテナ（２０－１、２０－２）はアクセス・ポイント（１４－１、１４－２）に配置され、受信する信号に応じて、さまざまな角度の信号到来方向に向けることができる。無線受信装置は２つの信号検出モードを利用する。第１モードでは、指向性アンテナ・アレーが無指向性利得パターンを有するように設定される。本発明を、第１ノード（１２－１－１、１２－２－２、１２－１－n）から受信したメッセージが第２ノード（１２－２－p）に転送される中継機能で使用するとき、記録された最良の受信方向が、第２ノード（１２－２－p）との通信のために取り出され、アンテナ・アレー（２０－１、２０－２）を用いて第２ノード（１２－２－p）に信号を送信するときに利用される。隣接ノードへ伝送するための最良のアンテナ角度の格納は、例えば、ＩＰアドレスを格納するルックアップ・テーブル（２５）に含まれる別



【特許請求の範囲】
【請求項１】
無線物理層信号プロトコルを用いて、指向性アンテナを使用する第１端末装置が第２端末装置と通信する無線データ通信システムを作動する方法であって、
データ・パケットを含む無線信号が前記第１端末装置で受信される時を決定し、
前記第２端末装置からの前記無線信号の第１部分から、前記第１端末装置にその無線信号を送信した、送信側である該第２端末装置の識別情報を決定し、
前記第２端末装置の前記決定された識別情報を用いて、前記指向性アンテナ・アレーのパラメータを決定し、
前記第２端末装置からの前記無線信号の後続部分を受信する間、前記パラメータに従って、前記指向性アンテナを前記識別された第２端末装置方向に向ける、
各ステップを含む方法。
【請求項２】
請求項１において、前記第１端末装置がアクセス・ポイントであり、前記第２端末装置が遠隔局である方法。
【請求項３】
請求項１において、前記第１端末装置が遠隔局であり、前記第２端末装置がアクセス・ポイントである方法。
【請求項４】
請求項１において、前記第１受信部分がデータ・フレームのプリアンブルである方法。
【請求項５】
請求項１において、前記受信信号の前記第１部分が一連のパケットの第１パケットである方法。
【請求項６】
請求項１において、前記無線信号の後続部分が前記フレーム中の後続部分である方法。
【請求項７】
請求項１において、前記無線信号の後続部分が一連の送信フレーム中の後続フレームである方法。
【請求項８】
請求項１において、前記指向性アンテナが複数のアンテナ素子からなる操作可能なアンテナ・アレーである方法。
【請求項９】
請求項４において、前記データ・フレームの前記プリアンブル部分が、該データ・フレームの後続部分に比べて頑丈な変調方式を用いて符号化されている方法。
【請求項１０】
請求項４において、前記プリアンブル部分が複数の可能なプリアンブル・フォーマットの内の１つを有する方法。
【請求項１１】
請求項４において、前記プリアンブル部分が送信側の識別情報を含み、前記ペイロードが後続の送信フレームである方法。
【請求項１２】
請求項１において、アンテナ・アレー・パラメータが前記第２端末装置の識別情報に関連付けされている方法。
【請求項１３】
請求項１２において、前記ユニット識別情報およびアンテナ・パラメータが、前記第１端末装置および第２端末装置間の通信に関連するネットワーク層アドレスに関連付けされたテーブルに格納されている方法。
【請求項１４】
請求項１３において、前記ネットワーク・アドレスがインターネット・プロトコル・アドレスであり、前記第１端末装置がネットワーク層メッセージ送信におけるルーティング機

能を実行する方法。

【請求項１５】

請求項1において、さらに、前記第２端末装置の識別情報からアンテナ・パラメータの識別情報を決定できない場合には、アンテナ・パラメータの設定を行うために、前記第２端末装置からの通信を受信するための最適方向を検索し、決定するステップを含む方法。

【請求項１６】

請求項１において、前記送信側第２端末装置の識別情報を決定するステップが、前記アンテナが無指向性モードで作動している間に受信される前記無線信号通信の一部分に基づく方法。

【請求項１７】

請求項１において、前記第２端末装置からの前記無線信号の第１部分の送信の間は頑丈な低位層レベル符号化変調方式を使用し、後続部分の送信の間は上位層レベルの符号化方式を使用する方法。

【請求項１８】

請求項１７において、前記識別情報が前記送信された無線信号の上位層レベル符号化部分内に位置している方法。

【請求項１９】

請求項１７において、前記無線信号の後続部分を受信する前に、前記指向性アンテナを最新の既知の方向に向ける方法。

【請求項２０】

請求項１９において、前記無線信号の前記後続部分は、後に送信されるデータ・フレームであってもよい方法。

【請求項２１】

請求項７において、さらに、前記送信側第２端末装置の識別情報が未知の場合には、指向性アンテナを操作して、通信を受信するための最適方向を決定するステップを含む方法。

【請求項２２】

請求項２１において、第１フレームの受信後に、前記識別情報を決定する方法。

【請求項２３】

請求項８において、さらに、前記最適方向を決定後、前記識別されたユニットからの無線信号を再度受信する場合に備えて、前記ユニット識別情報と共に前記最適方向情報を格納するステップを含む方法。

【請求項２４】

請求項１において、さらに、前記第１端末装置から第２端末装置に受信準備完了信号を送信し、

前記受信準備完了の応答に対する、前記第２端末装置からの受信を待ち、

前記応答が受信された場合、前記指向性アンテナのその時の設定が適正であると決定し、

前記応答が受信されない場合、送信を行うために別の角度を探索して決定する、

各ステップを含む方法。

【請求項２５】

無線物理層信号を用いて、第１端末装置が第２端末装置と通信する通信ネットワークを作動する方法であって、

アンテナ・アレーを無指向性モードに設定し、

前記第２端末装置からの送信を前記第１端末装置で受信し、

前記受信した送信信号から前記第２端末装置の識別情報を決定し、

前記指向性アンテナ・アレーを前記識別されたユニットに対して最新の既知位置の方向に向ける、

各ステップを含む方法。

【請求項２６】

請求項２５において、前記第１端末装置がアクセス・ポイントであり、前記第２端末装置が遠隔局である方法。

【請求項２７】
請求項２５において、前記第１端末装置が遠隔局であり、前記第２端末装置がアクセス・ポイントである方法。
【請求項２８】
請求項２５において、前記送信信号の第１部分がデータ・フレームのプリアンブルである方法。
【請求項２９】
請求項２５において、前記送信信号の第１部分が第１パケットである方法。
【請求項３０】
請求項２５において、前記送信信号の後続部分がデータ・フレーム中の後続部分である方法。
【請求項３１】
請求項２５において、前記送信信号の後続部分が、続いて送信されるパケットである方法。
【請求項３２】
請求項２８おいて、前記プリアンブル部分が送信側の識別情報を含む完全なデータ・フレームである方法。
【請求項３３】
請求項２５において、送信側である前記第２端末装置の識別情報を決定するステップが、前記アンテナが無指向性モードで作動している間に受信される前記信号の一部分に基づく方法。
【請求項３４】
請求項３３において、前記識別情報が前記送信信号の上位層レベル符号化部分内に含まれている方法。
【請求項３５】
請求項２５において、前記送信信号の後続部分を受信する前に、前記指向性アンテナを最新の既知の方向に向ける方法。
【請求項３６】
請求項２５において、さらに、前記第２端末装置の識別情報が決定されない場合には、一連の候補となる方向全体に渡って指向性アンテナを操作して、前記送信ユニットからの送信を受信するのに最適な方向を決定するステップを含む方法。
【請求項３７】
請求項３６において、さらに、前記最適方向を決定後、前記識別されたユニットからの送信信号を再度受信する場合に備えて、前記ユニット識別情報と共に前記最適方向情報を格納するステップを含む方法。
【請求項３８】
請求項３５において、さらに、既知の一連のパケットを連続して送信する間、パケット紛失に関係なくアンテナ・アレーを操作するステップを含む方法。
【請求項３９】
請求項３８において、さらに、パケット応答プロセスを用いて、パケットの紛失データを回復するステップを含む方法。
【請求項４０】
請求項３８において、さらに、無線リンク制御プロトコルを用いて、パケットの紛失データを回復するステップを含む方法。
【請求項４１】
無線物理層信号を用いて行われる通信において、指向性アンテナを使用する第１端末装置が第２端末装置と情報を交換する通信システムを作動する方法であって、
前記第２端末装置からの無線信号が第１端末装置で受信される時を決定し、
物理層より上位のプロトコル層においてメッセージを利用して、特定の第２端末装置からのデータの送信および再送信を制御し、

上位層プロトコルにおいて前記送信されたメッセージを用いて、前記アンテナ・アレーを操作する、
各ステップを含む方法。
【請求項４２】
請求項４１において、前記アンテナ・アレーの方向を最適化するために、プロトコル属性を用いて、前記データ・パケットを再送信する方法。
【請求項４３】
請求項４２において、前記プロトコル属性が前記第１端末装置から前記第２端末装置に返送される応答である方法。
【請求項４４】
請求項４３において、前記応答メッセージを中止することにより、前記第２端末装置から前記第１端末装置に前記データ・パケットを再送信させる方法。
【請求項４５】
請求項４４において、前記応答メッセージの中止が、Ｎ回の送信のうちの１つだけについてなされ、それにより、前記アンテナに適用するデューティ・サイクルの減少を実現する方法。
【請求項４６】
請求項４３において、さらに、前記第１応答の中止後、前記無線信号を受信している前記第２端末装置を識別して、該第２端末装置との過去の送信の履歴に基づき、前記アンテナの角度を決定する方法。
【請求項４７】
請求項４１において、前記プロトコル・ユニットが、送信要求および受信準備完了プロトコルデータユニットを用いて、特定の第２端末装置からのフレームの送信を保証する方法。
【請求項４８】
請求項４１において、前記上位層プロトコルが、特定の第２端末装置に送信を要求する集中制御機能エンティティである方法。
【発明の詳細な説明】
【技術分野】
【０００１】
本発明は一般に、無線データ伝送システムに関し、詳細には、前記システムにおいて指向性アンテナを利用する方法に関する。
【背景技術】
【０００２】
企業において、無線ＬＡＮ（ローカル・エリア・ネットワーク）は一般に、既存の有線ネットワークとクライアント・コンピュータのグループとの間の最終リンクとして構築されている。今日のビジネス環境の特徴として移動労働者の増加が挙げられる。彼らは時間の多くを職務的、組織的および地理的境界を越えたチームとして活動する。多くの場合、彼らの生産的な活動時間は、デスクから離れた場所でのミーティングである。したがって、携帯型コンピュータのユーザは、パーソナル・デスクトップを必要としないネットワークを介したデータ・ファイルへのアクセスを必要とする。無線ＬＡＮはこのような必要性を満たし、移動労働者にネットワーク・アクセスにおいて大きな自由度を提供する。このようなネットワークは、例えば会議室、カフェテリア、または遠方の支店のような、企業内のどこからでも情報へのアクセスを可能にする。無線ＬＡＮ接続は、ビルまたはキャンパス環境全体に渡って、企業ネットワークの全資源およびサービスへのアクセスを提供する。したがって、無線ＬＡＮは広範囲なビジネス分野において問題解決のための主流になりつつある。
【０００３】
無線ＬＡＮ配備の有効性に影響する１つの重要な問題点は、このような装置で利用可能なスループットに、歴史的に限界があったことである。１９９７年、ＩＥＥＥ（米国電気・

電子通信学会）で最初に規定された無線ＬＡＮ規格８０２．１１である、１秒当たり２メガビット（２Ｍｂｐｓ）のデータ・レートは、今日では、大部分のビジネス要求をサポートするには遅すぎると考えられている。より高速のデータ・レート伝送をサポートする必要性を認識して、最近ＩＥＥＥは最高１１Ｍｂｐｓのデータ伝送速度を規定する８０２．１１ｂ規格を批准した。８０２．１１ｂ規格を用いると、無線ＬＡＮは従来の有線Ｅｔｈｅｒｎｅｔ（登録商標）システムと同等のスループットを得られると期待される。同等のデータ速度を提供すると見込まれる新しく出現しつつある無線ネットワーク・システムには、ＨｏｍｅＲＦ、Ｂｌｕｅ　Ｔｏｏｔｈ、および第３世代ディジタル携帯電話システムが挙げられる。

【０００４】

ピアツーピア・ネットワークでは、個々のコンピュータ・ノードは同一周波数通信ネットワーク内で動作する。すなわち、これらシステムは符号分割多重アクセス（ＣＤＭＡ）のような信号変調方式を利用する。このＣＤＭＡでは、多数の端末ノードが同時に、同一無線周波数搬送波上で実際に伝送している。このようなシステムは、システム通信処理手順に関係しない装置の干渉に起因する、著しい信号の品質の低下を招く可能性がある。例えば、無線ＬＡＮシステムは一般に無許可の無線周波数帯域内で動作する。したがって、これらの帯域で動作する別のタイプの無線装置、すなわち公表されているＬＡＮ規格に準拠して動作する必要がない装置は規制できない。このような非規制システム・ノードからのこれらの伝送は、無線ＬＡＮの性能を著しく低下させる。データ・レートが高速になるに伴い、そのような干渉に影響を受け易くなる。

【０００５】

無線通信システムには、固有のさまざまな別の問題点が存在する。このような問題の１つはいわゆるマルチパスフェージング問題であり、これにより、送信側（基地局または別の移動加入者ユニットのいずれか）から伝送される無線周波数信号が、目的の受信側に達する途中で干渉を受ける。例えば信号は、伝送の直接経路内に存在しないビルのような物体により反射され、次に反射信号として受信者に伝送される。このような場合、受信側は実際には、同一無線信号を２度受信する、つまり本来の信号と反射信号とを受信する。それぞれの受信信号は同一周波数で伝送されるが、反射信号の伝送経路の方が長いことから、相互に位相がずれているため、本来の信号と反射信号とは相互に打ち消し合う傾向にある。この結果、受信された信号の欠落またはフェージングが発生する。

【０００６】

単一素子アンテナを利用する無線ユニットは、このようなマルチパス・フェージングの影響を大きく受ける。単一素子アンテナは、伝送信号が送信されてくる方向を決定する手段を持たず、また、それ自体により、任意の特定方向において信号を正確に検出または受信するように同調または減衰させることができない。したがって、指向性アンテナを用いると、マルチパスフェージングおよび同様の問題の両方をある程度軽減できることは公知である。

【発明の開示】

【０００７】

本発明は、アダプティブ指向性アンテナ・アレーを使用して、システム・ノード間で伝送される物理層無線信号の分離を支援する無線データ・ネットワークで利用される。コントローラは、放射および／または受信エネルギーの効果が最大になるようにアンテナ装置を構成できる。詳細には、アンテナ装置は一般に、複数のアンテナ素子と、受信および／または送信信号の位相を個々に変化させることができる位相器、受動素子等のような、アンテナ素子と同数の調整デバイスとを含む。このようにアンテナ装置は、送信または受信信号のさまざまな角度の到来方向に指向または操作できる。

【０００８】

アダプティブ・アンテナは、２つの別個の信号検出モードを利用する無線受信装置を使用する。第１受信モードでは、コントローラはアンテナを無指向性設定にする。このモードを使用するのは、受信信号が以前に識別されたことがない、またはリンク層コネクション

がまだ確立されていないときである。第２受信モードでは、アンテナは特定の指向角度に設定される。第２受信モードを使用するのは、受信信号が以前に識別されたことがあるか、またはリンク層コネクションが確立された後である。

【０００９】

受信信号を識別してアンテナ・アレー・モードを決定する、本発明の１つの実施形態によれば、複数のステップまたは動作状態からなる信号受信プロセスが実行される。

【００１０】

このプロセスの第１ステップでは、指向性アンテナ・アレーを制御して、該アンテナ・アレーに無指向性利得パターンを持たせる。このモードでは、最初に伝送信号を受信すると、その信号の先頭部分が有する特定の識別パラメータが検出される。例えばこれらパラメータは、無線ＬＡＮ信号の媒体アクセス制御（ＭＡＣ）層部分のプリアンブル部分に符号化されている発信元識別子であってもよい。

【００１１】

受信信号が以前に検出されたことがある場合、コントローラは指向性アンテナを最新の既知の最適方向に指向させるので、特定の検出信号の別の部分が受信される。

【００１２】

受信信号が以前に検出されたことがない場合、コントローラは指向性アンテナを走査させて最適受信信号メトリック（metric）が得られる方向設定を行う。この設定は、例えば、最適となるアンテナ角度の探索を開始し、最適角度（方向）の候補となる方向の各受信信号メトリックを検査することによりなされる。受信信号メトリックとしては、例えば、受信信号強度、ビット・エラー率、雑音電力、または他の同等のメトリックが挙げられる。アンテナの最適方向の設定が決定されると、その設定は保存され、同一の識別された信号が次に受信された際に用いられる。

【００１３】

プリアンブル部分に続くデータ・フレームのペイロード部分のような、同一信号の別の部分を受信するとき、指向性アンテナ・アレーは、候補となり得る新しい角度の走査を続行するように作動されて、指向性モードにおいて、常に最適の信号メトリックの探索を続行する。信号伝送が終了すると、その信号についての最新の既知の最適角度が、該信号の識別情報と共に保存されて、同一信号が次に受信された際に再び使用される。

第２実施形態では、本発明は、前述の実施形態と同様に、無指向性および指向性モードの両方を使用する。第２実施形態におけるプロセスの第１ステップでは、アンテナ・アレーは無指向性モードに設定される。次に受信信号の第１部分が検査され、送信要求（ＲＴＳ）メッセージのようなリンク層確立メッセージが受信される時を決定する。ＲＴＳが検出された後、ＲＴＳを送信した送信側の識別情報を使用して、最新の既知の信号到来角度を決定する。次に、アンテナ・アレーをその方向に向け、例えば、受信準備完了（ＣＴＳ）メッセージを送信する。ＣＴＳの応答が受信されると、後続ステップに進む。ＣＴＳ応答が受信された場合、アンテナは正しい方向に向けられていることが分かる。しかし、ＣＴＳ応答が受信されない場合、候補となる角度を走査して、アンテナ角度を再設定する必要があると推定される。

【００１４】

前述の実施形態は、アクセス・ノードまたは別の中央基地局ユニットにおいて特に有効である。

【００１５】

本発明のさらに別の実施形態は、以下の様に、アレーを使用する。送信要求（ＲＴＳ）のような最初のリンク層伝送は、指向性モードで目的とする受信側に送信できる。この実施形態は特に、送信側が、目的とする受信側に対して正しいと予測される方向に関する情報を格納している場合に有効である。次にユニットは、アンテナを同一角度に設定した状態で、受信モードにおいて受信準備完了（ＣＴＳ）指示の受信を待つ。

【００１６】

ＣＴＳが受信された場合、アンテナの方向は正しく、リンク層コネクションが確立されて

いると推定される。

【００１７】

しかし、ＣＴＳが指定の時間内に受信されない場合、コントローラはアンテナ・アレーを無指向性モードにリセットし、再度、リンク層コネクションの確立を試みる。

【００１８】

本発明がピアツーピア・ネットワークに使用される場合、本発明はまた、第１ノードから第２ノードへのメッセージを中継する機能を果たす装置に関連させて使用できる。この機能は有線インターネット・プロトコル（ＩＰ）ネットワークにおけるルータ機能と類似である。このような用途では、検出プロセスの間、最適受信信号メトリックを提供する角度は、前述のネットワーク内の複数のノードに対して、受信モードにおいて記録されている。したがって、第１ノードから第２ノードに中継する必要があるメッセージを受信するたびに、信号がその第２ノードから既に受信されたことがある場合、最適受信のための記録された方向が検索されて取り出され、この方向が、アンテナ・アレーを使用して信号を第２ノードに送信する場合に用いられる。隣接ノードへの伝送のための最適アンテナ角度の格納は、ＩＰアドレスに関連付けされたルックアップ・テーブル項目に含まれているような、別のルックアップ・テーブル機能に類似の方法で、制御機能により管理される。

【００１９】

本発明の前述およびその他の目的、特徴、および利点は、添付図面に示す本発明の好ましい実施形態の以下の詳細な説明で明らかになるであろう。図面では、同一参照符号は異なる図面においても同一部品を指す。図面は必ずしも縮尺通りでなく、本発明の原理を示すことに重点が置かれている。

【発明を実施するための最良の形態】

【００２０】

図１は、本発明が利用される無線データ通信ネットワーク１０の高次元ブロック図であり、このネットワーク１０は、例えば、複数の端末ノード１２およびインターネット１８のようなデータ・ネットワーク間の無線コネクションをアクセス・ポイント装置１４を介して提供するネットワークである。

【００２１】

詳細には、第１の無線ＬＡＮ（ローカル・エリア・ネットワーク）１１－１は、ノード１２－１－１、１２－１－２、．．．１２－１－ｎにより形成される。これらノード１２－１は、固有のフォーマットの無線信号を用いて、相互に、かつ第１アクセス・ポイント１４－１と通信する。指向性アンテナ・アレー２０－１は第１の無線ＬＡＮ１１－１内のアクセス・ポイント１４－１について使用される。アクセス・ポイント１４－１は、受信された無線周波数信号を、ゲートウェイ１６－１を介してインターネット通信するのに適するＴＣＰ／ＩＰフォーマットのような適正な有線フォーマットに変換する役割を果たす。

【００２２】

第１の無線ＬＡＮ１１－１と同じく、第２の無線ＬＡＮは、ノード１２－２－ｐ、アンテナ２０－２、アクセス・ポイント１４－２、およびゲートウェイ１６－２と同様な関係にある。

【００２３】

各ノード１２は、一般には無線ネットワーク・インタフェース・カード（ＮＩＣ）を装備した携帯型パーソナル・コンピュータ（ＰＣ）である遠隔端末を含む。個人用携帯情報端末（ＰＤＡ）、デスクトップ型コンピュータ装置などの別のタイプのコンピュータ装置、および他のネットワーク機能を有する装置も利用できる。

【００２４】

アクセス・ポイント（ＡＰ）１４－１は、無線ネットワーク１０とインターネット１８のような有線ネットワークとの間の一種のブリッジとして作用する。アクセス・ポイント１４－１は、無線ネットワークで使用される物理層信号に対して基地局として作用し、複数の無線ノード１２－１－１、．．．１２－１－ｎのアクセスを有線ネットワーク上に集める。アクセス・ポイント１４は通常、無線受信機および送信機、ならびにＩＥＥＥ８０２

．１１　Ｅｔｈｅｒｎｅｔインタフェースのような有線ネットワーク・インタフェースで構成される。アクセス・ポイント１４が別のネットワークへの接続を提供する場合、アクセス・ポイント１４は一般に、例えば、８０２．１ブリッジ規格に適合するブリッジング・ソフトウェア、およびファイアウォール等の他のソフトウェアを含む。したがって、アクセス・ポイント１４は、上位層データ・ネットワーク・プロトコルの観点からは、ルータまたはブリッジとして作用する。

【００２５】

標準無線ＬＡＮ信号方式装置に加えて、アクセス・ポイント１４－１はテーブル２５を備える。このテーブル２５は、ユニット識別情報のようなノード１２に関連する識別情報、および角度のような、各ノード１２に関連するアンテナ設定パラメータを格納できる。アレー・コントローラ３０は、角度を指定することにより、アンテナ２０－１を特定方向に向けることができる。アクセス・ポイント１４－１の信号受信装置は、受信信号強度指示（ＲＳＳＩ）、ビット・エラー率（ＢＥＲ）、雑音電力レベル、または受信信号品質を示す他のメトリックのような受信信号のメトリック（metric）を決定できる検出回路も含む。

【００２６】

図２Ａおよび２Ｂは、無線ＬＡＮ仕様ＩＥＥＥ　８０２．１１ｂに規定されているような、メッセージまたはフレーム構造のフォーマットを示す。メッセージは媒体アクセス制御（ＭＡＣ）層プリアンブル、ヘッダ、およびペイロード部分またはプロトコル指定データ・ユニット（ＰＳＤＵ）から構成される。ＩＥＥＥ　８０２．１１におけるメッセージは、図２Ａに示すメッセージに関連して用いられるようなロング（long）・プリアンブル・タイプ、および図２Ｂに示すようなショート（short）・プリアンブル・タイプのどちらでもよい。各フレーム・フォーマットは、それぞれのデータ・レートのサポートに関連付けされる。図２Ａに示すフレーム・フォーマットは、それぞれ1Ｍｂｐｓまたは２Ｍｂｐｓで符号化される二重バイナリー位相シフト・キーイング（ＤＢＰＳＫ）または二重直角位相シフト・キーイング（ＤＱＰＳＫ）のどちらかを用いて、ペイロード部分を変調する。図２Ｂに示すフレーム・フォーマットはＤＱＰＳＫを用いて、５．５Ｍｂｐｓまたは１１Ｍｂｐｓのデータ・レートを実現する。

【００２７】

上述のフレーム・フォーマットの両方では、フレームのプリアンブルおよびヘッダ部分は、データ・ペイロード部分に比べてより耐干渉性の大きい頑丈な符号化方式を利用する。これにより、雑音の存在中でもヘッダおよびプリアンブルの信頼性の高い検出を可能にする。

【００２８】

図２Ａおよび２Ｂに示されるどちらのフォーマットのプリアンブルも、例えばＳＦＤ部分に特定の送信側の指示を含む。

【００２９】

図３は、本発明による、無線ネットワーク信号を受信するプロセスのフロー・チャートを示す。この処理手順は、ノード１２から信号を受信すると同時にアクセス・ポイント１４で実行され、一般に物理層処理の間に実行される。

【００３０】

最初のアイドルステップ３００から次のステップ３１０では、各アクセス・ポイント１４に関連するアンテナ２０は、最初は無指向性モードに設定される。この無指向性モードでは、次に動作状態またはステップ３２０に入り、受信信号のプリアンブル部分および／またはヘッダが検出される。動作状態３３０では、受信信号の先頭部分が検査されて、一意的に識別される。受信信号が未知である場合、例えば信号を送出したノード１２が以前に識別されたことがない場合、アンテナは動作状態３２２で角度探索モードに設定される。このモードでは、アンテナ２０は、指向角度を段階的に変化させることで、最大受信信号強度、最大信号品質、最少のビット・エラー率（ＢＥＲ）または他の信号品質メトリックが得られる方向を見出す。この角度が決定されると、動作状態３２３では、この角度を記

録し、かつ（ノード１２の）デバイスに関連付けされるテーブル項目２５のようなデバイス識別情報に関連付けする。図１に示すテーブルは、アクセス・ポイント１４におけるメッセージ・ルーティング・テーブルの一部として、該アクセス・ポイント１４により維持される。

【００３１】

いずれにせよ、次に、アクセス・ポイント１４は動作状態３２４に入り、フレームの受信期間中に、フレームのペイロード・データ部分を受信する一方で、最適角度の調整を継続的に行う。フレームの受信が失敗または終了した場合、その時点における最新の最適既知角度がテーブルに記録され、プロセスは最初の動作状態３１０に戻る。

【００３２】

動作状態３３０で、信号が識別された場合、例えば、信号が送信ノード１２から以前に受信されたことがある場合、処理手順は動作状態３２５に進み、そのノード１２に対応する最新の既知角度がテーブル２５内で検索される。次に、コントローラ３０はこの最新の既知角度を使用して、アンテナ・アレーをその最新の既知位置（角度）の方向に向ける。その後アレーは、動作状態３２６において、少なくとも信号のペイロード部分を受信している間は、この最新の既知位置に留まる。アクセス・ポイント１４は、ペイロード部分の受信中に動作状態３２６から動作状態３２４に入ってもよく、その場合、アンテナ角度の調整が継続して行われるため、最適角度に関する情報の更新がテーブル２５に記録される。

【００３３】

ユニットが中継モードにある場合、アクセス・ポイント１４は、動作状態３２６から動作状態３２８に入り、最適受信角度を同一ノードへの送信に使用する。

【００３４】

図４は図３に示したプロセスの一部を変更した処理手順の図であり、この手順も本発明により使用できる。図４のプロセスのステップ数は、図３のステップ数にほぼ一致する。例えば、最初のアイドルステップ３００の次のステップ３１０で、アンテナ２０は最初に無指向性モードに設定される。ただし、この実施形態では、上位層レベルの信号方式が検査される。例えば、ステップ３１５において、送信要求（ＲＴＳ）メッセージがリンク層のような層において検出される。ステップ３３０では、そのメッセージが再度検査され、送信元が既知の識別情報を有するか否か決定される。既知の識別情報を有している場合、図３に示したプロセスと同様にステップ３２５および３２６に進み、ステップ３２５で送信元に関連付けされた最新の既知角度が決定され、ステップ３２６でアンテナ２０がその最新の既知角度の方向に向けられる。この場合、次にステップ３４０で、ユニットは、最新の既知角度に設定されているアンテナを用いて、受信準備完了（Clear to Send＝ＣＴＳ）メッセージを送信する。

【００３５】

ただし、ステップ３３０で、検出されたＲＴＳの識別情報が既知でない場合、動作状態３２２で角度探索が行われ、ステップ３２３でＩＤ、および最適受信状態となる角度が記録される。次に、図３に示したプロセスと同様にステップ３２４に進み、アクティブ・ペイロード・データが受信されている間、角度は継続して調整される。信号検出が失敗したときおよび／またはメッセージの終了（ＥＯＭ）を受信したとき、ステップ３４５に入る。

【００３６】

なお、動作状態３２６においてアンテナが最新の既知角度に向けられる場合、図４に示すように、ステップ３４０において、受信準備完了（ＣＴＳ）メッセージが送信される。次に、ステップ３４２で、ＣＴＳ応答を待つ。応答は一般に、所定の時間内に受信されるが、受信されなかった場合は、タイムアウト状態が現れる。応答が受信されると、動作状態３４４で、その特定角度が最適であると推定され、次に、処理手順はステップ３２４に進んでもよい。ただし、ステップ３４２でタイムアウトが発生する場合、アンテナ２０の角度が最適でないと推定され、したがって、角度探索が動作状態３２２において行われる必要がある。

【００３７】

図４に示した前述の方法は、複数の遠隔加入者ユニットと通信する、アクセス・ノードまたは中央基地局に適用する場合に有効である。

【００３８】

さらに、本発明の別の実施形態は、加入者ユニットに以下の利点を提供できる。図５はその一連の動作を示す。第１ステップ５００では、アンテナは指向性モードに設定される。例えば、加入者ユニットは一般に、基地局が存在する、候補となる方向に関する所定の情報を有する。ステップ５１０では、送信要求（ＲＴＳ）メッセージが指向性モードで送信される。ステップ５２０では、基地局からの受信準備完了（ＣＴＳ）メッセージが受信された場合、ステップ５２２において、アンテナの方向設定が最適であると推定され、リンク層通信がステップ５２４において設定される。

【００３９】

しかし、ステップ５２０においてＣＴＳがタイムアウト期間内に受信されない場合、アンテナ設定は最適でないと推定される。したがって、ステップ５２８においてアンテナは無指向性モードに設定され、ステップ５４０においてＲＴＳメッセージが送信される。次に、図３および／または図４に示したプロセスと同様に、ステップ５４４において角度探索を実行して、アンテナを最適に設定し、ステップ５４８においてその設定が記録される。

【００４０】

図６は、典型的なネットワーク・コンピュータ環境において送信できる一連の上位レベルメッセージを示す。詳細には、アクセス・ポイント１４−１または遠隔局１２のどちらかである発信局がメッセージ６１０を送信する。メッセージ６１０は１つまたは複数のパケットで構成され、このパケットは前述のプリアンブル、ヘッダ、およびペイロード部分を有する。メッセージは、比較的詳細なメッセージでもよく、またはコネクションを確立して、別の情報を送信する要求のような比較的簡単なメッセージでもよい。

【００４１】

宛先局は、メッセージ６１０の受信に応答して、応答メッセージ６１２を返送すると予測される。この応答メッセージ６１２は、プリアンブル部分と、詳細には、公知の応答（ＡＣＫ）フォーマットである、ヘッダまたはペイロード部分を有するヘッダ部分とを有する。上位層プロトコルは、例えば、リンク層で実行できる。

【００４２】

本発明はこれら上位層のプロトコル・ユニットを使用して、別のプロトコルを呼び出し、アンテナの調整に役立てることができる。

【００４３】

応答メッセージ６１２は、宛先局において適正なメッセージ６１０を受信すると同時に送信される。ただし、応答が宛先局から送信されない動作状態６１４も存在する。これは一般に、宛先局において、メッセージが所定の時間内に受信されない場合に発生する。この状態で、発信局はメッセージ６１０を再送信する必要性を認識する。この応答プロトコルは、インターネット・データ通信で使用されるＴＣＰ／ＩＰ（Transmission Control Protocol/Internet Protocol）で代表されるデータ通信ネットワーク内で幅広く使用されている上位層プロトコルの典型である。

【００４４】

物理層プロトコルが、データ・フレームを復調する時間を持てない、および／またはプリアンブル部分内に送信局の識別情報を含まないなどの、特定の状況において、上位層プロトコル情報を使用する必要がある。そのようなプロトコルは、特定方式の復調を実行することなしに、送信機端末の識別情報を知る方法がないという問題を有する。ただし、その結果として、信号を復調する時間が無い。例えば、フレーム全体を処理する後まで、受信品質を決定することができない。これはフレームに用いられる特定の符号化に依存する。さらに、特定プロトコルはプリアンブル部分を使用するが、それらのプリアンブル期間は短すぎるため、アンテナ・アレーを適正な方向に向けようとしても、時間内にその最適方向を確定することはできない。例えば、８０２．１１ｂ規格はこの点に関して条件に適合し得る。しかし、８０２．１１ａ無線ＬＡＮ規格のようなプロトコルは十分なプリアンブ

ル期間を提供できない場合がある。さらに、無線ＬＡＮプロトコルは、Ｅｔｈｅｒｎｅｔと同様な類似の無線リンク・プロトコル上で機能する。詳細には、肯定応答無線リンク・プロトコルが使用される。例えば、適正に受信されたパケットは通知されるが、不適性に受信されたパケットは通知されない。したがって、無線リンク・プロトコル層および／または上位レベル層で非応答試験が実行される。

【００４５】

基本的に、上述の試験は図７に示すプロセスに従って行われる。最初のアイドル動作状態７００の次の動作状態７１０では、アンテナ・アレー２０は最初に無指向性に設定される。

【００４６】

次の、動作状態７１２では、伝送パケットを受信する。このパケットを正しく受信すると、動作状態７１４において、通常では送信される応答６１２（図６）の送信が中止される。したがって、ユニットは、応答が行われない動作状態６１４（図６）に入る。これにより、動作状態７１６において、アンテナ角度が設定される。動作状態７１４における応答の中止により、動作状態７１８においてそのパケットを再び受信する。動作状態７２０では、２回目に受信したパケットの受信品質と１回目に受信したパケットのそれとを比較する。受信品質が適正でない場合、プロセスは動作状態７１４に戻り、その２回目に受信したパケットに対する応答が再度中止される。ステップ７１４～７２０は、動作状態７２０において許容できる受信パケット品質が得られるまで、連続して実行される。パケット品質が容認されると、プロセスは動作状態７２２に進み、応答が直ちに送信される。次に、設定角度がユニットの識別情報と共に記録され、そのユニットとの後続の通信に備える。

【００４７】

なお、特定の場合には、ステップ７１２におけるパケットの受信時にユニットの識別情報を決定できる場合、図３に示したのと同様に、動作状態７１６において角度は、そのパケットが２回目に受信された際により精度よく設定できる。例えば、遠隔ユニットの識別情報が動作状態７１２において受信したパケットから決定できる場合、ステップ７１４～７２０に関連して行われる角度探索は迅速に行われる。

【００４８】

ここでの重要な点は、上位層プロトコルを使用してパケットの再送信を行うことにより、アンテナ・アレー設定を最適化することである。同様の結果を得るために、別のプロトコル属性またはユニットを使用できる。例えば、いわゆるＰＣＦまたはＨＣＦモードを用いる。特定のプロトコルによりコンテンション・フリー（無競合）ウィンドウを設定できる。ＰＣＦモードでは、特定の期間中にどのユニットが次に送信するかに関して、アクセス・ポイントにより制御できる最適角度を見出す手段が提供される。したがって、ユニットの識別情報が予め既知であれば、受信に先立ち、アンテナを最新の既知の方向（角度）に向けて通信することができる。その結果、制御メッセージは、無指向性モードの間に設定でき、遠隔ユニットに送信するとき、ＨＣＦ（Hybrid Coordination Function :複合制御器機能）モードにおける指向性モードを決定できる。

【００４９】

次に、図８について詳細に説明する。８０２．１１アクセス・ポイント１４は基本的に２つのモード、すなわち、ＤＣＦ（Distributed Coordination Function：分散制御機能）モード８１０およびＰＣＦ（Point Coordination Function：集中制御機能）モード８３０を含む。ＤＣＦモード８１０では、通信は基本的にコンテンション・ベースであり、そのため、加入者ユニット１２のいずれか1つが、任意の時点でアクセス・ポイント１４へのメッセージの送信を試みることができる。場合により、ＰＣＦモード８３０において、コンテンション・フリーの通信が可能なモードを提供する。このように、ＰＣＦモード８３０の間、システムは、特定の加入者ユニット１２が、電波への独占的なアクセスを有し、また他の加入者ユニット１２と衝突することなく、アクセス・ポイント１４にメッセージを送信することができる、ことを保証する。

【００５０】

したがって、ＤＣＦモード８１０に関連する動作状態８１２では、アクセス・ポイント１４は、後にコンテンション・フリー領域が与えられる特定の加入者ユニット１２の各々から散発的に送信要求を受け取る。最終的に、ＰＣＦモードが動作状態８３０において実行される。この動作状態８３０において、アンテナは最初に無指向性モード８３２に設定される。次の動作状態８３４では、ビーコン信号が全加入者ユニット１２に送られて、ＰＣＦモードに設定されたことが知らされる。このビーコン信号は、全ユニット１２に対して送信されるポーリング情報を持つ信号であり、それらユニット１２がその信号に返答すれば、コンテンション・フリー期間が許可される。ポーリング信号が動作状態８３４から送出される。動作状態８３４におけるポーリング信号への返答は、ＰＣＦモードの間にコンテンション・フリーのアクセスを許可される、加入者ユニット１２のうちの１つの特定の識別子を決定する。なお、ＰＣＦモードの間は、複数の加入者ユニット１２の各々は順次アクセスの独占的使用を許可されるか、またはコンテンション・フリーのアクセス期間を与えられる。

【００５１】

コンテンション・フリー期間を要求した加入者ユニット１２の送信申込みスケジュールに従って、動作状態８３４においてアクセス・ポイント１４は、リスト上の１番目ユニット、つまり一番最初にビーコン信号に対して返答したユニットに送信を許可する。ポーリング・メッセージは、特定の識別された加入者ユニット１２に対して、動作状態８３６において最新の既知の位置または適正な角度にアンテナを向けることにより送信される。次にステップ８３８において、この特定のＰＣＦメッセージがコンテンション・フリー・メッセージとして送信される。ＰＣＦモードを要求した加入者ユニットのそれぞれが、順にコンテンション・フリー期間を与えられ終わるまで、ステップ８３４～８３８が連続して実行される。コンテンション・フリー期間中、各加入者ユニット１２が順次アクセスを許可される度に、動作状態８３６において、アンテナがユニット１２に対して適正な方向に向けられた後、その加入者ユニット１２に対してＰＣＦメッセージが送信される。動作状態８３８において、コンテンション・フリー実行処理が終了すると、アクセス・ポイントは動作状態８３９においてアンテナ・アレー２０を無指向性モードに戻し、動作状態８４０において、コンテンション・フリー期間終了メッセージを全加入者ユニットに送信することにより、それらユニットが、ＰＣＦモードが終了しており、またシステムが動作状態８１０のＤＣＦモードに復帰していることを認知できるようにすることができる。

【００５２】

本発明を好ましい実施形態により図示し、説明してきたが、当業者には、添付の特許請求項に包含される本発明の範囲から逸脱することなく、形態または細部の各種の変更が実行可能であることは理解されるであろう。

【図面の簡単な説明】

【００５３】

【図１】本発明を実施するシステムのブロック図である。

【図２Ａ】伝送信号をフォーマットするのに用いられる媒体アクセス制御（ＭＡＣ）層のデータ・フレームまたはメッセージの例を示す。

【図２Ｂ】伝送信号をフォーマットするのに用いられる媒体アクセス制御（ＭＡＣ）層のデータ・フレームまたはメッセージの例を示す。

【図３】第１実施形態による受信信号を処理するための、アンテナ・コントローラで実行される一連のステップを示すフロー図である。

【図４】第２実施形態によるアンテナ・コントローラによるプロセスを示すフロー図である。

【図５】コントローラが実行するさらに別のプロセスを示すフロー図である。

【図６】メッセージとそれの応答を示す図である。

【図７】応答中止を用いてアンテナ角度の設定を確認する一連のステップを示すフロー図である。

【図８】コンテンション・フリー（無競合）期間を用いてアンテナ角度の設定を確認する

一連のステップを示すフロー図である。

【符号の説明】

【００５４】

１１　無線ＬＡＮ
１２　ノード（加入者ユニット）
１４　アクセス・ポイント
１６　ゲートウェイ
１８　インターネット
２０　アンテナ
２５　ルックアップ・テーブル
３０　アレー・コントローラ

【図１】

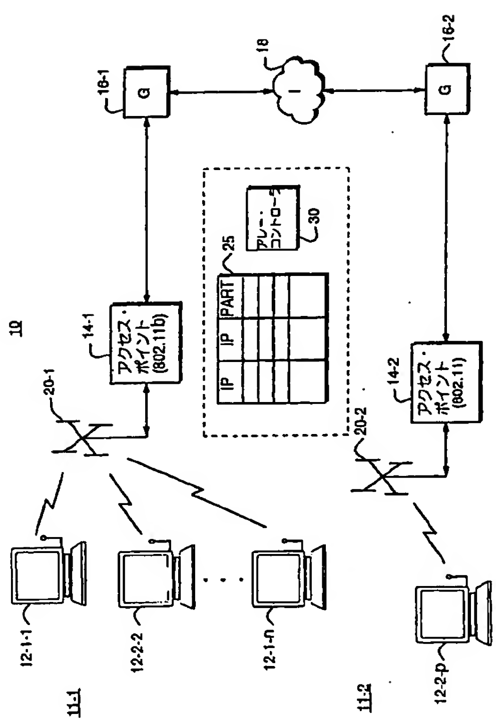


FIG. 1

【図２Ａ】

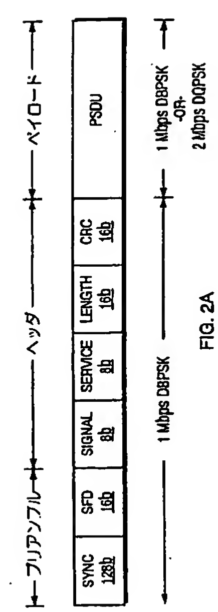
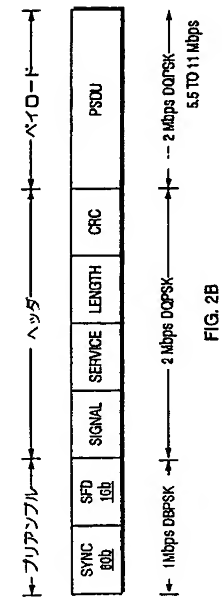


FIG. 2A

【図２Ｂ】



【図３】

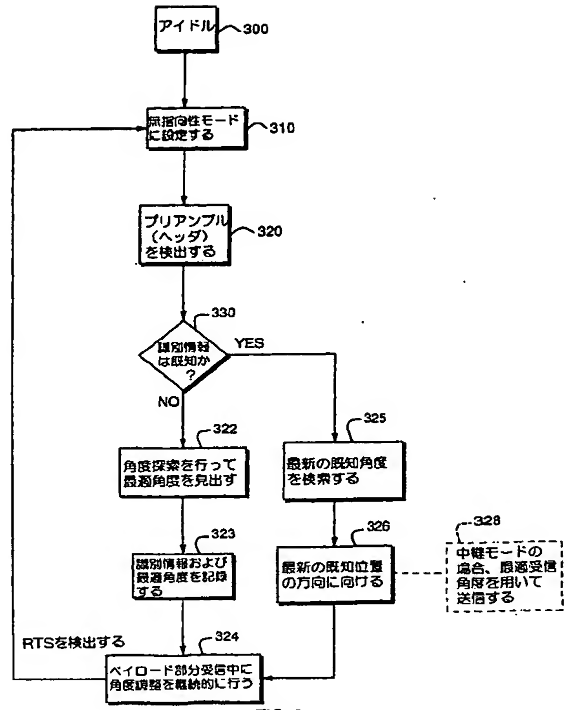


FIG. 3

【図４】

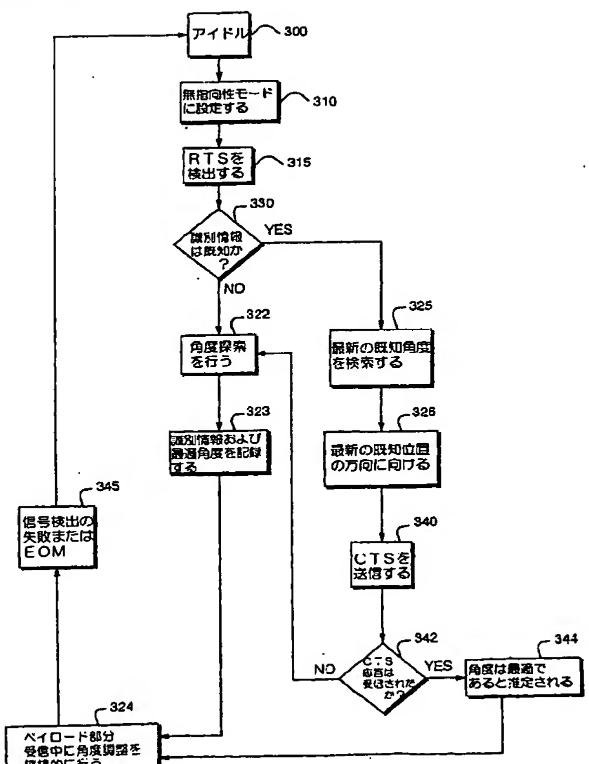


FIG. 4

【図５】

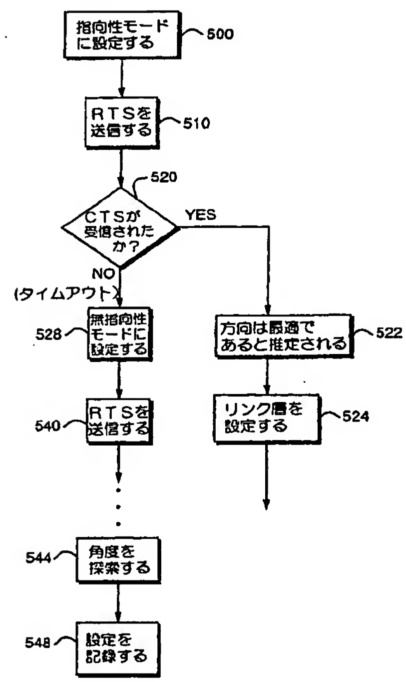


FIG. 5

【図６】

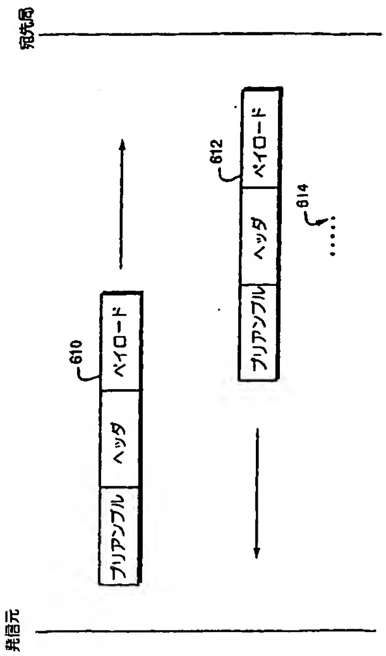


FIG. 6

【図７】

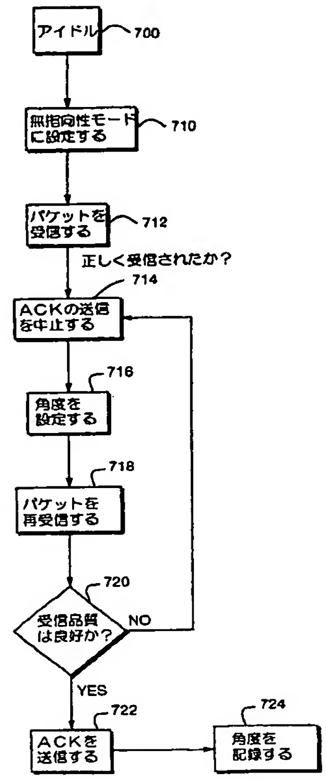


FIG. 7

【図８】

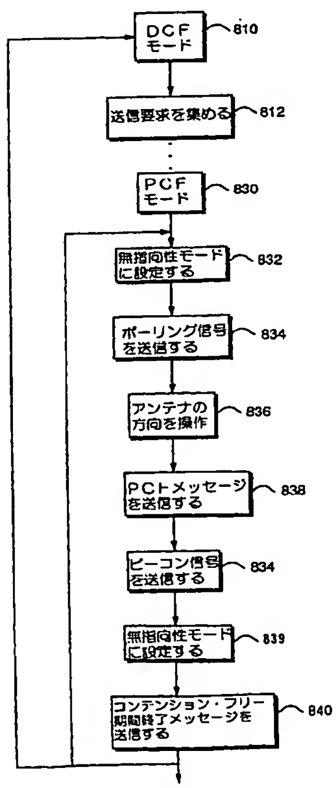


FIG. 8

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(71) Applicant: TANTIVY COMMUNICATIONS, INC. [US/US]; 1450 S. Babcock Street, Melbourne, FL 32901 (US).

(72) Inventor: PROCTOR, James, A., Jr.; 258 Sea View Street, Melbourne, FL 32951 (US).

(74) Agents: THIBODEAU, David, J., Jr. et al.; Hamilton, Brook, Smith & Reynolds, P.C., 530 Virginia Road, P.O. Box 9133, Concord, MA 01742-9133 (US).

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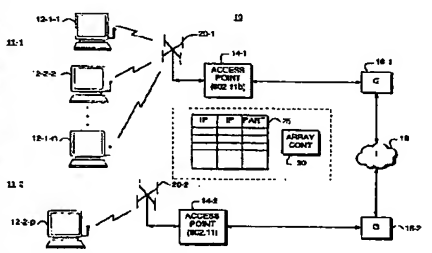
(54) Title: METHOD OF DETECTION OF SIGNALS USING AN ADAPTIVE ANTENNA IN A PEER-TO-PEER NETWORK



(57) Abstract: An adaptive antenna signal identification process to provide increased interference rejection in a wireless data network such as a wireless Local Area Network (LAN). The adaptive antenna is located at an access point and can be steered to various angle of arrival orientations with respect to received signals. Associated radio receiving equipment utilizes two distinct signal detection modes. In a first mode, the directional antenna array is set to have an omni directional gain pattern. In this mode, certain identification parameters of an initial portion of a received signal are detected, such as a source identifier. If the received signal has not been previously detected, then the antenna array is scanned determine a direction setting that provides a best received signal metric. Once the best directional setting for the received signal, that setting is saved for future use in receiving the same signal. If the received signal has been previously detected, the system instead will steer the directional antenna to the last known best direction for reception for the particular detected signal. As further portions of the same signal are received, such as payload portions of a data frame, the directional antenna array can continue to scan potential new best angles. When the invention is deployed in a relay function, where messages received from a first node are to be forwarded to a second node, the recorded direction of its best reception is retrieved for the second node and used when the antenna array is used to transmit the signal to the second node. Storage of the best antenna angle for propagation to neighbor nodes can be handled by control functions in a manner that is analogous to other router lookup tables, such as being contained in a lookup table that stores IP addresses.

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

METHOD OF DETECTION OF SIGNALS USING AN ADAPTIVE ANTENNA IN A PEER-TO-PEER NETWORK

BACKGROUND OF THE INVENTION

This invention relates generally to wireless data transmission systems and in particular to a technique for using directional antennas in such systems.

In corporate enterprises, wireless Local Area Networks (LANs) are usually implemented as a final link between existing wired networks and a group of client computers. Today's business environment is characterized by an increasingly mobile work force, who spend much of their time working in teams that cross functional, organizational and geographic boundaries. Often their most productive times occur in meetings that take place away from their desks. Users of portable computing equipment therefore need access to their data files through networks that reach far beyond their personal desktops. Wireless LANs fit well into this environment, providing much needed freedom in network access to mobile workers. Such networks provide access to information from anywhere within an enterprise, such as from a conference room, cafeteria, or even a remote branch office. Wireless LAN connectivity affords access to the full resources and services of a corporate network across a building or campus setting. As such, they are on the verge of becoming a mainstream solution for a broad range of business applications.

One critical issue affecting the effectiveness of wireless LAN deployment has been the historically limited throughput available with such equipment. The 2 Mega bits per second (Mbps) data rate specified by the original Institute of Electrical

and Electronics Engineers (IEEE) wireless LAN standard 802.11, dated 1997, is now considered to be too slow to support most business requirements. Recognizing the need to support additional higher data rate transmissions, the IEEE recently ratified an 802.11b standard that specifies data transmission speeds of up to 11 Mbps. With the 802.11b standard, wireless LANs are expected to be able to achieve throughput comparable to the legacy wired Ethernet infrastructure. Emerging wireless networking systems that promise to provide comparable data speeds include Home RF, BlueTooth, and third generation digital cellular telephone systems.

In these peer-to-peer networks, the individual computer nodes operate in a same frequency communication network. That is, these systems utilize signal modulation schemes such as Code Division Multiple Access (CDMA) wherein a number of end nodes are actually transmitting on a same radio frequency carrier at the same time. Such systems may experience significant quality degradation due to the interference of equipment that is not participating in system communication processes. For example, wireless LAN systems typically operate in unlicensed radio frequency bands. Other types of radio equipment operate in these bands, equipment that is not required to operate in accordance with the promulgated LAN standards, and therefore, cannot be controlled. These transmissions from such non-system nodes can significantly reduce the performance of a wireless LAN. As data rates increase, susceptibility to such interference also increases accordingly.

Various other problems are inherent in wireless communication systems. One such problem is the so-called multipath fading problem whereby a radio frequency signal transmitted from a sender (either a base station or another mobile subscriber unit) may encounter interference enroute to an intended receiver. The signal may, for example, be reflected from objects such as buildings that are not in a direct path of transmission but then are redirected as a reflected version of the original signal to the receiver. In such instances, the receiver actually receives two versions of the same radio signal: the original version and a reflected version. Since each received signal is at the same frequency but out of phase with one the other due the longer transmission path for the reflected signal, the original and reflected

signals may tend to cancel each other out. This results in dropouts or fading of the received signal.

Radio units that employ single element antennas are highly susceptible to such multipath fading. A single element antenna has no way of determining a direction from which a transmitted signal is sent and cannot be tuned or attenuated to more accurately detect or receive a signal in any particular direction operating by itself. It is known that directional antennas can therefore alleviate both the multipath fading and similar problems to some extent.

SUMMARY OF THE INVENTION

The present invention is used in a wireless data network that employs an adaptive directional antenna array to assist in isolating physical layer radio signals transmitted between system nodes. A controller can configure the antenna apparatus to maximize the affect of radiated and/or received energy. Specifically, the antenna apparatus typically includes multiple antenna elements and a like number of adjustable devices such as phase shifters, passive elements, or the like, that may be independently changed to effect the phase of received and/or transmitted signals. The antenna apparatus can therefore be oriented or steered to various angle of arrival orientations with respect to transmitted or received signals.

The adaptive antenna makes use of radio receiving equipment that utilizes two distinct signal detection modes. In a first receive mode, the controller sets the antenna to an omni-directional setting. This mode is used when a received signal has not yet been identified or the link layer connection established. A second receiver mode, in which the antenna is set to a specific directional angle, is used after a receive signal has been identified or a link layer connection established.

According to an embodiment of the invention that uses identification of the received signal to determine the antenna array mode, a multi-step process is employed.

In a first step of the process, the directional antenna array may be controlled such that it has an omni-directional gain pattern. In this mode, when an incoming

transmission is first received, certain identification parameters of an initial portion of the signal are detected. For example, these may be a source identifier encoded in a preamble portion of a Media Access Control (MAC) layer portion of a wireless Local Area Network (LAN) signal.

If the received signal has been previously detected, the controller will steer the directional antenna to a last known best direction for reception of further portions of the particular detected signal.

If the received signal has not been previously detected, then the controller scans the directional antenna to determine a direction setting that provides a best received signal metric. This can proceed, for example, as an angular search of possible antenna angle settings, and testing a received signal metric for each candidate direction. The received signal metric may, for example, be received signal strength, bit error rate, noise power, or other comparable measure. Once the best directional setting for the antenna is determined, that setting is saved for future use in receiving the identified signal.

As further portions of the same signal are received, such as payload portions of the data frame which follow a preamble portion, the directional antenna array can be operated to continue to scan potential new angles, continuing to look for the best signal metric in a directive mode all the time. Once a signal transmission is concluded, the last known best angle for that signal, along with an identification of the signal, for use in future reception of that same signal.

In a second embodiment, the invention also employs both the omni-directional and directional modes of the antenna, as in the previous embodiment. In a first step of this process, the antenna array is set to an omni-directional mode. A first portion of a received signal is then examined, to determine when a link layer establishment message, such as a Request to Send (RTS) message is received. After an RTS is detected, identification information for the sender of the RTS is used to determine a last known angle of arrival. The array is then steered to this direction for subsequent transmission of, for example, a Clear to Send (CTS) message. A follow-on step may be employed when an acknowledgement of the CTS is then

listened for; if the CTS acknowledgement is received, then it is known that the antenna is steered to a proper direction. However, if an acknowledgement of the CTS is not received, it is assumed that the antenna angle must be re-established through scanning candidate angles.

The foregoing embodiment is particularly useful in an access node or other central base unit.

Yet another embodiment of the invention can use the array as follows. An initial link layer transmission, such as a Request to Send (RTS) may be sent to an intended receiver in a directional mode. This embodiment is particularly useful where a sender has stored information as to a likely direction for the intended receiver. The unit then waits to receive a Clear to Send (CTS) indication in a receive mode with the antenna set to the same angle.

If the CTS is received, then it is assumed that the direction is correct, and a link layer connection is established.

However, if the CTS is not received within a specified time, the controller resets the array to an omni-directional mode, and attempts again to establish the link layer connection.

When the invention is deployed in a peer-to-peer network, it may also be used in connection with a device that is responsible for relaying messages from a first node to a second node. This functionality is an analogous to a router function in a wireline Internet Protocol (IP) network. In such an application, during the detection process, the angle providing the best received signal metric was recorded during the receive mode for a number of nodes in the networks as described above. Therefore, whenever a message is received from a first node that needs to be relayed to a second node, if signals have already been received from that second node, then the recorded direction of its best reception is retrieved and used when the antenna array is used to transmit the signal to the second node. Storage of the best antenna angle for propagation to neighbor nodes can be handled by control functions in a manner that is analogous to other router lookup table functions, such as being contained in a lookup table entry associated with IP addresses.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram of a system in which the invention is implemented.

Figs. 2A and 2B provide examples of Media Access Control (MAC) layer data frames or messages that may be used to format transmitted signals.

Fig. 3 is a sequence of steps performed by an antenna controller in order to process received signals according to a first embodiment.

Fig. 4 is a process diagram for the antenna controller according to a second embodiment.

Fig. 5 is yet another process which the controller may perform.

Fig. 6 illustrates a message and its acknowledgement.

Fig. 7 is a sequence of steps using acknowledgement suppression to confirm antenna angle setting.

Fig. 8 is a sequence of steps using contention-free periods to confirm antenna angle setting.

The foregoing and other objects, features and advantages of the invention will be apparent from the following more particular description of preferred embodiments of the invention, as illustrated in the accompanying drawings in which like reference characters refer to the same parts throughout the different views. The drawings are not necessarily to scale, emphasis instead being placed upon illustrating the principles of the invention.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

Fig. 1 is a high level block diagram of a wireless data communication network 10 in which the invention may be deployed, such as network for providing wireless connectivity between a number of end nodes 12 and a data network such as the Internet 18 through access point equipment 14.

Specifically, a first wireless Local Area Network (LAN) 11-1 formed by the nodes 12-1-1, 12-1-2, ... 12-1-n. These nodes 12-1 communicate with each other and a first access point 14-1 using specially formatted radio signals. A directional

antenna array 20-1 is used with the access point 14-1 in the first wireless LAN 11-1. The access point 14-1 is responsible for converting received radio frequency signals to their appropriate wired format such as the TCP/IP format suitable for Internet communications through a gateway 16-1. The gateway 16-1 may be a router, switch, or other internetworking device.

A similar second wireless LAN 11-2 involves the nodes 12-2-p, antenna 20-2, access point 14-2, and gateway 16-2.

Each of the nodes 12 include a remote station which is typically a portable Personal Computer (PC) equipped with a wireless network interface card (NIC). Other types of computing equipment such as Personal Digital Assistants (PDAs), desktop computing equipment, and other networkable devices are possible.

The access point (AP) 14-1 acts as a sort of bridge between the wireless network 10 and wired networks such as the Internet 18. The access point 14-1 acts as a base station for the physical layer signaling used in the wireless network, aggregating access for multiple wireless nodes 12-1-1, ... 12-1-n onto the wired network. The access point
14 usually consists of radio receiver and transmitter equipment and a wired network interface such as an IEEE 802.11 Ethernet interface. If the access point 14 is to provide connectivity to other networks, it may typically include bridging software conforming to, for example, 802.1 Bridging Standard, and other software such as firewalls and the like. It therefore acts as a router or bridge, from the perspective of higher layer data networking protocols.

In addition to standard wireless LAN signaling equipment, the access point 14-1 also contains a table 25 which is capable of storing identification information for the nodes 12 such as a unit identification and an associated antenna setting parameters, such as an angle. An array controller 30 that permits steering of the particular direction of the antenna 20-1 such as by specifying an angle. Signal receiving equipment in the access point 14-1 also contains detection circuits that are capable of determining a received signal metric, such as Received Signal Strength

Indication (RSSI), Bit Error Rate (BER), noise power level, or other such measures of receive signal quality..

Figs. 2A and 2B illustrate the format of a message or frame structure such as described in the wireless LAN specification IEEE 802.11b. The message consists of a Media Access Control (MAC) layer preamble, header, and payload portion or Protocol Specific Data Unit (PSDU). The messages in IEEE 802.11 may be either a long preamble-type as used in the connection with the message shown in Fig. 2A, as well as the short preamble-type as shown in Fig. 2B. The different frame formats are associated with supporting different data rates. The frame format shown in Fig. 2A uses either Double Binary Phase Shift Keying (DBPSK) or Double Quadrature Phase Shift Keying (DQPSK) encoded at, respectively, 1 Mbps or 2 Mbps to modulate the payload portion. The frame format in Fig. 2B utilizes DQPSK to realize data rates of 5.5 Mbps or 11 Mbps.

Note also that for both frame formats, the preamble and header portions of the frame utilize a more robust encoding scheme than the data payload portions. This permits more reliable detection of the header and preamble in the presence of noise.

The preamble of either formats shown in Fig. 2A or 2B include an indication of the particular senders, such as in the SFD portion.

Fig. 3 illustrates a flow chart of a process for receiving wireless network signals in accordance with the invention. The process is performed in an access point 14 as it receives signals from nodes 12, and may typically be carried out during physical layer processing.

From a first idle step 300, the antenna 20 associated with the respective access point 14 is initially set into an omni-directional mode. In this omni-directional mode, a state 320 is then entered in which the preamble portion and/or header of a received signal is detected. In state 330, the initial portion of the received signal is examined to identify it uniquely. If the received signal is unknown, e.g., the node 12 which originated the signal has not been seen before, the antenna is then set in an angle search mode in state 322. In this mode, the antenna

20 is therefore stepped through a sequence of directional angles to find a direction of maximum received signal strength, signal quality, lowest Bit Error Rate (BER) or other signal quality metric. In state 323, when this angle is determined, it is recorded and associated with the device identification information, such as a table entry 25 associated with that device. The table as shown in Fig. 1 may be kept by the access point 14 as part of its message routing table.

In any event, the access point 14 may then enter a state 324 in which during active receptions, the optimum angle is continuously adjusted while receiving the payload data portion of the frame. If reception of the frame is then lost or otherwise completed, then the last best known angle is recoded in the table, and processing returns to the initial state 310.

If from state 330 the signal was able to be identified, e.g., a signal has been previously received from the transmitting node 12, then processing proceeds to a state 325 in which the last known angle is looked up in the table 25. This last known angle is then used by the controller 30 to steer the array to the last known position. The array then remains in this last known position at least for reception of the payload portion of the signal in state 326. From there, the state 324 may continue to be entered as the payload portion is being received whereby the angle is continuously adjusted while it is active and any updates are then recorded in the table 25.

The state 328 may be entered from state 326 if the unit is in a relay mode, where the best received angle may be used a subsequent transmissions to that same node.

Fig. 4 is a diagram of a slightly modified process that may also be used according to the present invention. The number of steps of the process in Fig. 4 correspond, more or less, to the steps of Fig. 3. For example, from a first idle step 300, the antenna 20 is initially set in step 310 to an omni-directional mode. However, in this embodiment higher layer level signaling is examined. For example, in step 315, a Request to Send (RTS) message is detected such as at a link layer. In step 330, the message is again examined to see if the originator has a known identification. If so, steps 325 and 326 proceed as previously where the last

known angle associated with that sender is determined in step 325 and the antenna 20 is steered to the last known angle in step 326. In this instance, the unit will then send a Clear to Send (CTS) message in step 340 with the antenna now set to the last known angle.

If however, back in step 330, if the identification of the detected RTS is not known, then an angle search proceeds in state 322 and the ID and angle of the best reception state is recorded in step 323. Step 324 continues as previously where the angle may be adjusted while active payload data is being received. Step 345 may be entered when the signal detection is lost and/or an end of message (EOM) is received.

Returning attention to an instance in which the last known angle is steered to in state 326, a Clear to Send (CTS) message is sent step 340. Next, a CTS acknowledgement is waited for in step 342. The acknowledgement would typically be received within a predetermined amount of time or otherwise a time-out condition exists. If the acknowledgement is received, then the specified angle is presumed to be okay and in state 344 and then processing may proceed to step 224. However, if a time-out does occur in step 342, then it is presumed that the angle to which the antenna 20 was steered is bad and therefore the angle search state 322 must be entered.

The foregoing methods are particularly useful in applying an application to an access node or central base station unit wherein it is intended to service a number of remote subscriber units.

However, another embodiment of the invention can be applied to advantage in a subscriber unit as follows. This set of operations is illustrated in Fig. 5. In a first step 500, the antenna is set to a directional mode. For example, it is typically common that the subscriber will have the given information with respect to its candidate direction in which the base station exists. In step 510, a Request to Send (RTS) message is sent in a directional mode. In step 520, if a Clear to Send (CTS) message is received back from the base station, then it can be presumed that the

antenna direction setting is okay in step 522 and the link layer communications may proceed in step 524.

If however, in step 520 there is no CTS received within a time-out period, then it is presumed that the antenna is incorrectly set. Thus, an omni-directional mode is entered in step 528 and the RTS message is sent in step 540. Processing then proceeds from that point similar to that described in Fig. 3 and/or Fig. 4, i.e., an angle search is performed to properly set the antenna in step 544 and the setting is recorded in step 548.

Fig. 5 illustrates a sequence of higher level messages that may be sent in a typical network computer environment. Specifically, a source station which may either be the access point 14-1 or remote stations 12, sends a message 610. The message 610 may consist of one or more packets that have the previously described preamble, header, and payload portions. The message may be a relatively detailed message or may be a relatively simple message such as a request to set up a connection and send further information.

In response to receipt of the message 610, the destination station is expected to return and acknowledgement message 612. This acknowledgement message 612 may have a preamble portion and a header portion that specifically has a header or payload portion that is a known acknowledgement (ACK) format. The higher layer protocol may be, for example, implemented at a link layer.

The present invention may make use of these higher layer protocol units to invoke other protocols to help train the antenna.

The acknowledgement message 612 is sent upon receipt of a proper message 610 at the destination station. However, situations may also exit 614 in which no acknowledgement is sent from the destination. This is typically done if the message is not received within a predetermined period of time at the destination. In that manner, the source will know to attempt to retransmit the message 610. This acknowledgement protocol is typical of higher layer protocols in widespread usage in data communication networks typical of the Transmission Control Protocol/Internet Protocol (TCP/IP) protocol used in Internet data communications.

It may become necessary to use the higher layer protocol information in certain circumstances wherein the physical layer protocols do not permit time to demodulate the data frame and/or do not contain identification of the sending station in the preamble portion. Such protocols present a problem in that there is no way to know transmitter ends without some type of demodulation taking place. However, there is, in turn, no time in which to or there is no time in which to demodulate the signal. For example, it may not be possible to determine quality of a reception until after an entire frame is processed. This may depend upon the specific coding used for the frame. In addition, certain protocols may use preamble portions that are too short in duration to identify the best direction in time for this antenna array to be affectively steered to the appropriate direction. For example, 802.11B Standard is potentially acceptable in this regard. However, protocols such as the 802.11A Wireless LAN Standard may not provide sufficient duration preamble. In addition, the wireless LAN protocols work on a similar radio link protocol that is similar to Ethernet. In particular, a positive acknowledgement radio link protocol is used. For example, if correctly received packets are acknowledged whereas incorrectly received packets are not. Thus, the non-acknowledgement test can be performed at a radio link protocol layer and/or higher level layers.

Essentially, the process is shown as in Fig. 6. For an initial idle state 600, tenant array 20 is first steered to an omni-directional state.

In a next state 712, a transmission is received. When this packet is received correctly, a state 714 is entered in which the acknowledgement 612 that would normally be sent is suppressed. Therefore, the unit enters a mode in which no acknowledgement is sent 614. This permits entry to a state 716 in which the angle for the antenna may be set. The suppression of the acknowledgement in state 714 causes a second receipt of the packet in state 718. In this second receipt in state 720, the received quality is compared. If the received quality is not adequate, then the process loops back to state 714 in which the acknowledgement is suppressed once again. Step 714 through 720 are continuously executed until an acceptable received packet quality is determined in state 720. When this occurs, control passes to state

722 in which an acknowledgement is presently sent. The set angle is then recorded with the identification of the unit for subsequent communication with that unit.

It should be understood that in certain instances upon receipt of the packet in 712, if the identification of the unit can be determined, then the angle may be more appropriately set upon the second try in state 716, such as in shown in Fig. 3. For example, if the identification of the remote unit can be made from the received packet in state 712, then the angle search associated with step 714 through 720 can proceed more expeditiously.

What is important to note here is that the higher layer protocol is being used to force a retransmission of a packet for the purpose of optimizing the antenna array setting. Other protocol attributes or units could be used for similar results. For example, a contention-free window can be set up by certain protocols using a so-called PCF or HCF mode. In the PCF mode, a means is provided for discovering the best angle that can be controlled by an access point as to which units will be transmitting during a certain period of time. Thus, the identification of the unit being known in advance, the antenna can be steered to the last known direction for the communication prior to its receipt. Thus, the control messages may be set up while an omni-directional mode then when transmitting to the remote unit, the directed mode can in HCF or Hybrid Coordination Function can be determined.

Turning attention more particularly to Fig. 8, an 802.11 access point 12 has essentially two modes, including a distributed correlation function (DCF) mode 810 and a point coordination function (PCF) mode 830. In the DCF mode, communication is basically contention-based whereby any one of the subscriber units 12 may be allowed to attempt to send messages to the access point 14 at any point in time. The PCF mode 830 is entered into from time to time to provide a mode in which contention-free communication is possible. Thus, while in the PCF mode, the system guarantees to a particular subscriber unit 12 that it will be able to have exclusive access to the airwaves and send messages to the access point 814, free of any collision with other subscriber units 12.

Thus, in one state 812 associated with DCF mode 810, the access point 14 receives requests on a sporadic basis from particular subscriber units 12 to be granted contention-free areas (CF) at a later time. Eventually, the PCF mode is entered in state 830. In this state, the antenna is first sent to an omni-directional mode 832. In a next state 834, a beacon signal is sent to all subscriber units 12 to indicate that the PCF mode is being entered into. This is a signal to all units to listen for upcoming polling information to determine if they will be granted a contention-free period. A poll signal is then sent out at state 834. A response to the poll signal in state 834 determines a particular identifier of one of the subscriber units 12 which is to be granted contention-free access during the PCF mode. It should be understood that during any given PCF mode, a number of different subscriber units 12 may be granted exclusive use or may be granted a contention-free period one after the other.

From its schedule of subscriber units 12 that have requested contention-free periods, the access point in state 834 polls the first such unit on its list. The poll message is sent by steering the antenna to the last known location or correct angle for the particular identified subscriber unit 12. This particular PCF message is then sent in step 838 as a contention-free message. Steps 834 through 838 are then continuously executed until each of the subscriber units that had requested a CF eventually be granted their turn at a contention-free period. Upon each subsequent such subscriber unit 12 being accessed during the contention-free period, the antenna will be steered to its respective appropriate direction in the state 836 prior to sending the associated PCF message for the particular subscriber unit 12. At the end of the contention-free processing in state 838, the access unit may then steer the antenna array 20 back to an omni-directional mode so that in a state 840, a contention-free period end message may be sent to all of the subscriber units so that they may understand that the end of PCF mode has been reached and that the system is then now returning to a DCF mode in state 810.

While this invention has been particularly shown and described with references to preferred embodiments thereof, it will be understood by those skilled in

the art that various changes in form and details may be made therein without departing from the scope of the invention encompassed by the appended claims.

CLAIMS

What is claimed is:

1. A method for operating a wireless data communication system in which a first station communicates with a second station using a wireless physical layer signaling protocol, and the first station making use of a directional antenna, the method comprising the steps of:

determining when a wireless signal containing a data packet is being received by the first station;

determining an identification of a transmitting second station that transmitted the wireless signal to the first station from a first portion of the transmission from the second station;

using the determined identification of the second station to determine parameters for the directional antenna array; and

during reception of a subsequent portion of the signal transmission from the second station, steering the directional antenna according to the parameters for the identified second station.

2. A method as in claim 1 wherein the first station is an access point, and the second station is a remote station.

3. A method as in claim 1 wherein the first station is a remote station and the second station is an access point.

4. A method as in claim 1 wherein the first received portion is a preamble of a frame.

5. A method as in claim 1 wherein the first portion of the received signal is a first packet in a series of packets.

6. A method as in claim 1 wherein the subsequent transmission is a later portion of the frame.

7. A method as in claim 1 wherein the subsequent transmission is a later frame in a series of transmitted frames.

8. A method as in claim 1 wherein the directional antenna is a steerable array of multiple antenna elements.

9. A method as in claim 4 wherein the preamble portion of the data frame is encoded with a more robust modulation scheme than the following portions of the transmission.

10. A method as in claim 4 wherein the preamble portion may have one of a plurality of possible preamble formats.

11. A method as in claim 4 wherein the preamble portion contains sender identification and the payload is regarded as subsequently sent frames.

12. A method as in claim 1 wherein antenna array parameters are associated with the identification of the second station.

13. A method as in claim 13 wherein the unit identification and antenna parameters are stored in a table associated with a network layer address associated with forwarding communications between the first and second station.

14. A method as in claim 13 wherein the network address is an Internet Protocol address and the first station performs routing functions for network layer messaging.

15. A method as in claim 1 additionally comprising the step of:
if it is not possible to determine an identification of antenna parameters from the identification of the second station,
searching for an antenna parameter setting to determine an optimum direction for receipt of communications from the second station.

16. A method as in claim 1 wherein the step of determining an identification of the transmitting second station occurs from a portion of the communication received while the antenna is operating in an omni-directional mode.

17. A method as in claim 1 wherein a robust, lower coded modulation type is used during transmission of a first portion, and a higher coded modulation type is used during a later portion of the transmission from the second station.

18. A method as in claim 17 wherein the identification information is located in the higher coded portion of the transmission.

19. A method as in claim 17 wherein the directional antenna is steered to the last known direction before later portions of the transmission are received.

20. A method as in claim 19 wherein the later portions of the transmission may also be subsequently transmitted data frames.

21. A method as in claim 7 additionally comprising the step of:

if identification of the transmitting second station is unknown, steering the directional antenna to determine an optimum direction for receipt of communications.

22. A method as in claim 21 wherein the identification is determined after the reception of a first frame.

23. A method as in claim 8 additionally comprising the step of:
after the optimum direction is determined, storing the direction information, together with the unit identification information, for use in subsequent processing of signals received from the identified unit.

24. A method as in claim 1 additionally comprising the step of:
sending a Clear to Send (CTS) indication from the first station to the second station;
listening for receipt of an acknowledgement of the Clear to Send signal;
if such acknowledgement is received, determining that the present setting of the directional antenna is sufficient; and
if the acknowledgement is not received, then determining a different angle for the transmission.

25. A method for operating a communication network in which a first station communicates with a second station using wireless physical layer signaling and comprising the steps of:
setting an omni-directional mode for an antenna array;
receiving transmissions at the first station from the second station;
determining an identification of the second station from the received transmission; and

steering the directional antenna array in the direction of the last known location for the identified unit.

26. A method as in claim 25 wherein the first station is an access point and the second station is a remote station.

27. A method as in claim 25 wherein the first station is a remote station and the second station is an access point.

28. A method as in claim 25 wherein the first portion of the transmission is a preamble of a data frame.

29. A method as in claim 25 wherein the first portion of the transmission is a first packet.

30. A method as in claim 25 wherein a subsequent transmission is a later portion of a data frame.

31. A method as in claim 25 wherein a subsequent transmission is a later transmitted packet.

32. A method as in claim 28 wherein the preamble portion is a complete data frame containing identification of a sender.

33. A method as in claim 25 wherein the step of determining identification of the transmitting second station occurs from a portion of the transmission received while the antenna is operating in the omni-directional mode.

34. A method as in claim 33 wherein identification is contained in a higher coded portion of the transmission.

35. A method as in claim 25 wherein the directional antenna is steered to the last known direction before later portions of the transmission begin.

36. A method as in claim 25 additionally comprising the step of:
if identification of the second station is not determined, steering the directional antenna through a series of candidate directions to determine an optimum direction for receipt of communications from the transmitting unit.

37. A method as in claim 36 additionally comprising the step of:
after the optimum direction is determined, storing the direction information, together with the unit identification information, for use in subsequent processing of signals received from the identified unit.

38. A method as in claim 5 additionally comprising the step of:
during a sequence of known series of transferred packets, steering the antenna array without concern for packet loss.

39. A method as in claim 38 additionally comprising the step of:
employing a packet acknowledgement mechanism to recover any lost data.

40. A method as in claim 38 additionally comprising the step of:
relying on a radio link control protocol (RLP) mechanism to recover lost packets.

41. A method of operating a communication system in which a first and second station exchanges information, the communication occurring using wireless physical layer signaling, and the first station making use of a directional antenna, the method comprising the steps of:

determining when a wireless signal is being received from the second station at the first station;

utilizing messages at a protocol layer higher than the physical layer to control transmission and retransmission of data from a specific second station; and

using the transmitted messages at higher layer protocols to steer the antenna array.

42. A method as in claim 41 wherein the protocol attributes are used to force a retransmission of the data packet for the purpose of optimizing the antenna array steering.

43. A method as in claim 42 wherein the protocol attribute is an acknowledgement (ACK) returned from the first station to the second station.

44. A method as in claim 43 wherein the acknowledgement message is suppressed in order to force a retransmission from the second station to the first station.

45. A method as in claim 44 wherein the acknowledgment suppression is performed only upon one of a number, N, of transmissions to provide for reduction in duty cycle of the adaptation of the antenna.

46. A method as in claim 43 additionally comprising the step of:

after the first acknowledgement suppression, identifying the second station from which the transmission is being received to determine an angle for the antenna based upon the history of past transmissions from the specific second station.

47. A method as in claim 41 wherein the protocol units utilize Request to Send (RTS) and Clear to Send (CTS) protocol data units to ensure transmission of frames from a specific second station.

48. A method as in claim 41 wherein the protocol units are Point Coordination Function (PCF) entities that only request a specific second station to transmit.

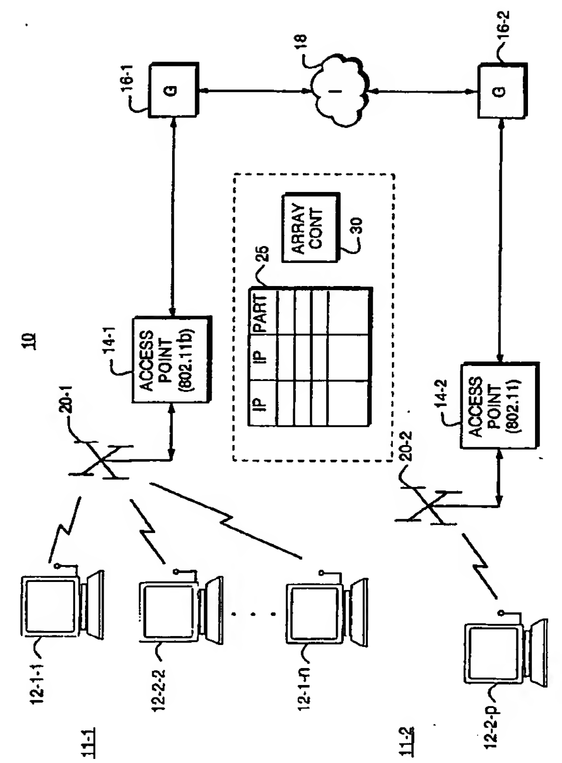
10
16-1
G
18
I
16-2
G
ACCESS POINT (802.11b)
14-1
25
IP
IP
PART
ARRAY CONT
30
20-1
20-2
ACCESS POINT (802.11)
14-2
12-1-1
12-2-2
12-1-n
12-2-p
11-1
11-2

FIG. 1

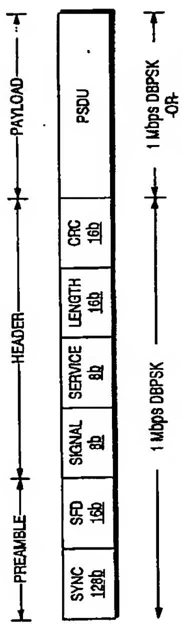
PREAMBLE
HEADER
PAYLOAD
SYNC 128b
SFD 16b
SIGNAL 8b
SERVICE 8b
LENGTH 16b
CRC 16b
PSDU
1 Mbps DBPSK
1 Mbps DBPSK
-OR-
2 Mbps DQPSK

FIG. 2A

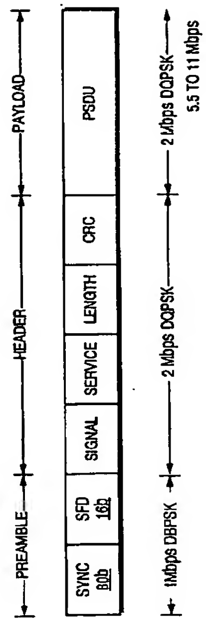
PREAMBLE
HEADER
PAYLOAD
SYNC 80b
SFD 16b
SIGNAL
SERVICE
LENGTH
CRC
PSDU
1Mbps DBPSK
2 Mbps DQPSK
2 Mbps DQPSK
5.5 TO 11 Mbps

FIG. 2B

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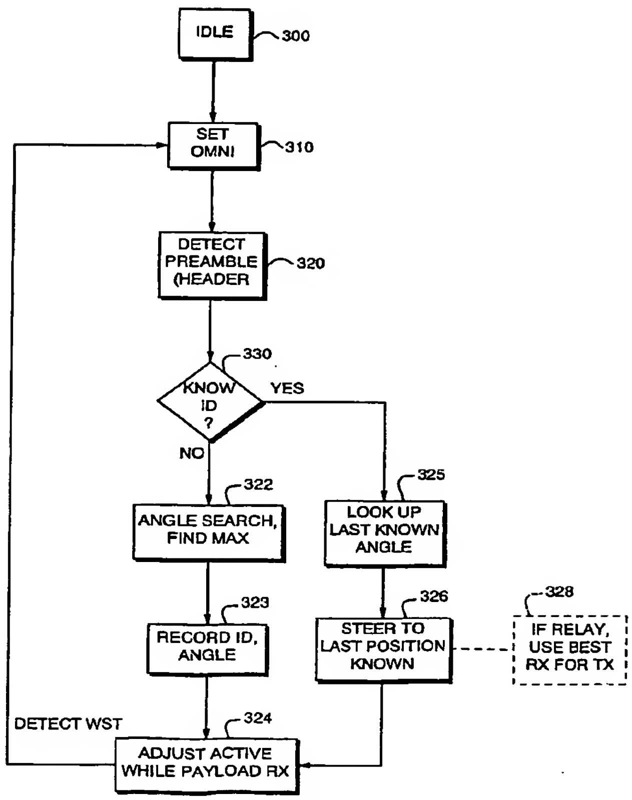
IDLE
300
SET OMNI
310
DETECT PREAMBLE (HEADER
320
330
KNOW ID ?
YES
NO
322
ANGLE SEARCH, FIND MAX
325
LOOK UP LAST KNOWN ANGLE
323
RECORD ID, ANGLE
326
STEER TO LAST POSITION KNOWN
328
IF RELAY, USE BEST RX FOR TX
DETECT WST
324
ADJUST ACTIVE WHILE PAYLOAD RX

FIG. 3

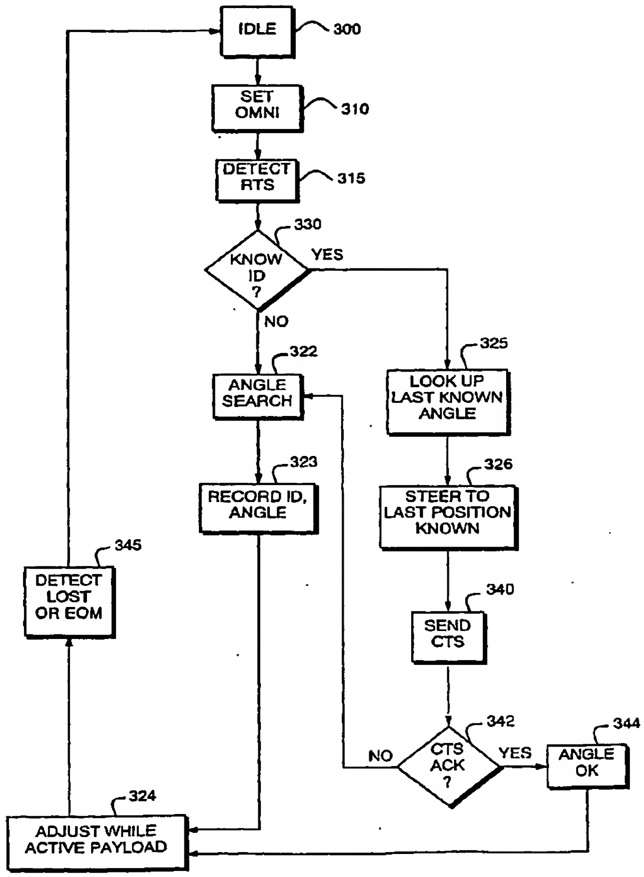
IDLE
300
SET OMNI
310
DETECT RTS
315
330
KNOW ID ?
YES
NO
322
ANGLE SEARCH
325
LOOK UP LAST KNOWN ANGLE
323
RECORD ID, ANGLE
326
STEER TO LAST POSITION KNOWN
345
DETECT LOST OR EOM
340
SEND CTS
342
CTS ACK ?
NO
YES
344
ANGLE OK
324
ADJUST WHILE ACTIVE PAYLOAD

FIG. 4

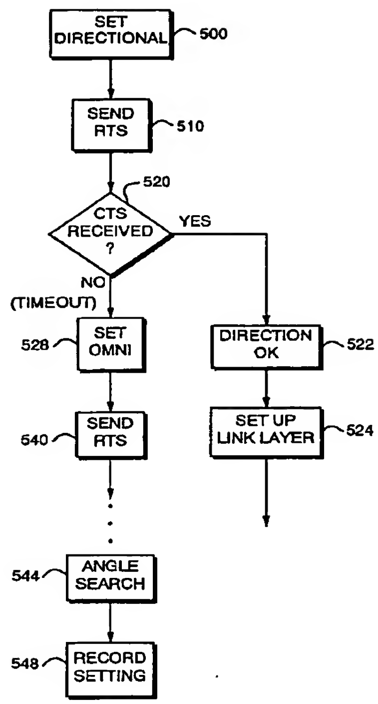
SET DIRECTIONAL
500
SEND RTS
510
520
CTS RECEIVED ?
YES
NO (TIMEOUT)
SET OMNI
528
DIRECTION OK
522
SEND RTS
540
SET UP LINK LAYER
524
ANGLE SEARCH
544
RECORD SETTING
548

FIG. 5

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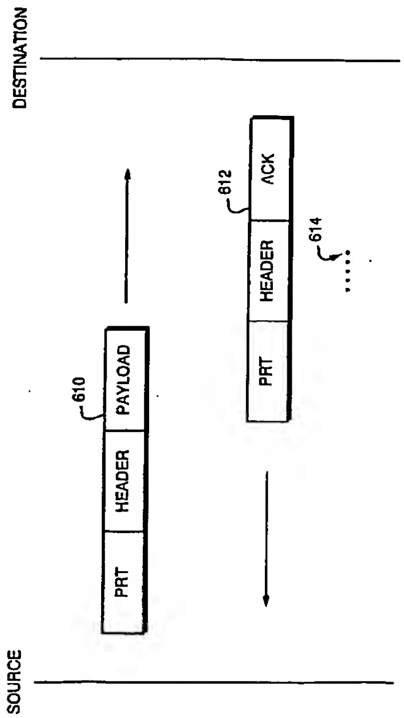
DESTINATION
SOURCE
610
PRT
HEADER
PAYLOAD
612
PRT
HEADER
ACK
614

FIG. 6

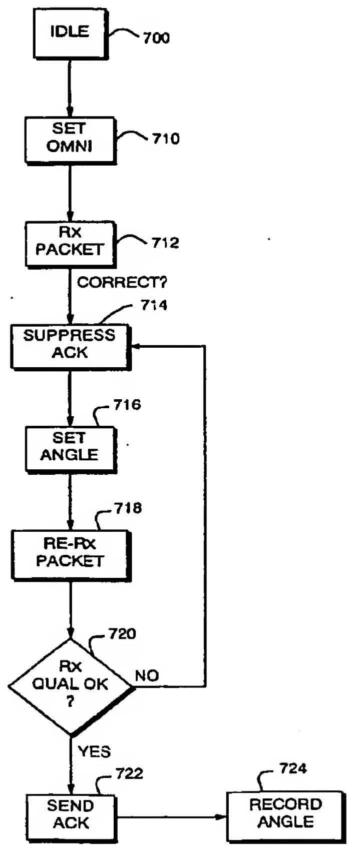
IDLE
700
SET OMNI
710
RX PACKET
712
CORRECT?
714
SUPPRESS ACK
716
SET ANGLE
718
RE-RX PACKET
720
RX QUAL OK ?
NO
YES
722
SEND ACK
724
RECORD ANGLE

FIG. 7

8/8

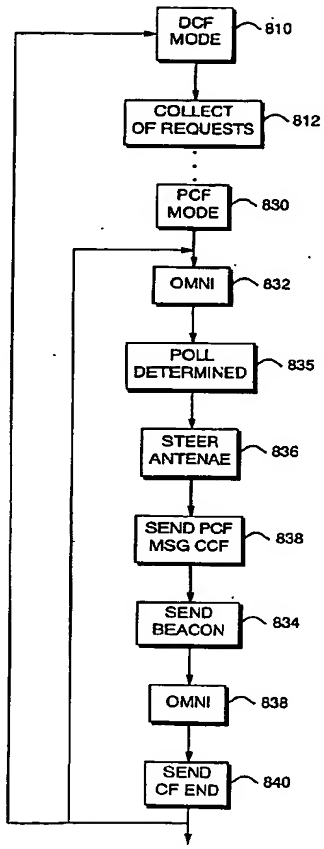
DCF MODE
810
COLLECT OF REQUESTS
812
PCF MODE
830
OMNI
832
POLL DETERMINED
835
STEER ANTENAE
836
SEND PCF MSG CCF
838
SEND BEACON
834
OMNI
838
SEND CF END
840

FIG. 8

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(71) Applicant: TANTIVY COMMUNICATIONS, INC. [US/US]; 1450 S. Babcock Street, Melbourne, FL 32901 (US).

(72) Inventor: PROCTOR, James, A., Jr.; 258 Sea View Street, Melbourne, FL 32951 (US).

(74) Agents: THIBODEAU, David, J., Jr. et al.; Hamilton, Brook, Smith & Reynolds, P.C., 530 Virginia Road, P.O. Box 9133, Concord, MA 01742-9133 (US).

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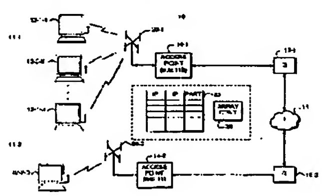
For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: METHOD OF DETECTION OF SIGNALS USING AN ADAPTIVE ANTENNA IN A PEER-TO-PEER NETWORK



(57) Abstract: An adaptive antenna signal identification process to provide increased interference rejection in a wireless data network such as a wireless Local Area Network (LAN) (11-1, 11-2). The adaptive antenna (20-1, 20-2) is located at an access point (14-1, 14-2) and can be steered to various angle of arrival orientations with respect to received signals. Associated radio receiving equipment utilizes two distinct signal detection modes. In a first mode, the directional antenna array is set to have an omni-directional gain pattern. When the invention is deployed in a relay function, where messages received from a first node (12-1-1, 12-2-2, 12-1-n) are to be forwarded to a second node (12-2-p), the recorded direction of its best reception is retrieved for the second node (12-2-p) and used when the antenna array (20-1, 20-2) is used to transmit the signal to the second node (12-2-p). Storage of the best antenna angle for propagation to neighbor nodes can be handled by control functions in a manner that is analogous to other router lookup tables, such as being contained in a lookup table (25) that stores IP addresses.

WO 03/023895 A3

【国際調査報告】

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US02/29147

A. CLASSIFICATION OF SUBJECT MATTER
IPC(7) : H04B 7/00; H04Q 7/00
US CL : 370/334;455/25
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 370/310,328,329,331,332,334,335,336,338,339,345,350,458,500,503,504,509;455/7,25,91,55,97,120,121

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Please See Continuation Sheet

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	KALIS et al. Relative Direction Determination in Mobile Computing Networks. IEEE Instrumentation and Measurement Technology Conference. 21-23 May 2001. Volume 3. Pages 1479-1484.	1-12,15-18,21,24-34,36,38-41,43-45,47-48 --- 13-15,19-20,22-23,35,37,42,46
X	NASIPURI et al. A MAC Protocol for Mobile Ad Hoc Networks Using Directional Antennas. IEEE Wireless Communications and Networking Conference. 23-28 September 2000. Pages 1214-1219.	1-3,5,8,12,15-16,24-27,33-34,41,47
X	KO et al. Medium Access Control Protocols Using Directional Antennas in Ad Hoc Networks. IEEE INFOCOM. 26-30 March 2000. Pages 13-21, especially pages 13-15.	1-8,12,15-16,24-34,36,38-41,43-45,47-48
X	HORNEFFER et al. Directed Antennas in the Mobile Broadband System. IEEE INFOCOM. 24-28 March 1996. Pages 704-712, especially 704-708.	1,25,41
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☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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Date of mailing of the international search report
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INTERNATIONAL SEARCH REPORT

PCT/US02/29147

Continuation of B. FIELDS SEARCHED Item 3:
IEEE database
search terms: antenna*, directional, packet*, frame*

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(81)指定国　AP(GH,GM,KE,LS,MW,MZ,SD,SL,SZ,TZ,UG,ZM,ZW),EA(AM,AZ,BY,KG,KZ,MD,RU,TJ,TM),EP(AT,BE,BG,CH,CY,CZ,DE,DK,EE,ES,FI,FR,GB,GR,IE,IT,LU,MC,NL,PT,SE,SK,TR),OA(BF,BJ,CF,CG,CI,CM,GA,GN,GQ,GW,ML,MR,NE,SN,TD,TG),AE,AG,AL,AM,AT,AU,AZ,BA,BB,BG,BR,BY,BZ,CA,CH,CN,CO,CR,CU,CZ,DE,DK,DM,DZ,EC,EE,ES,FI,GB,GD,GE,GH,GM,HR,HU,ID,IL,IN,IS,JP,KE,KG,KP,KR,KZ,LC,LK,LR,LS,LT,LU,LV,MA,MD,MG,MK,MN,MW,MX,MZ,NO,NZ,OM,PH,PL,PT,RO,RU,SD,SE,SG,SI,SK,SL,TJ,TM,TN,TR,TT,TZ,UA,UG,UZ,VC,VN,YU,ZA,ZM,ZW

(72)発明者　プロクター・ジェームズ・エー・ジュニア
アメリカ合衆国，フロリダ州　３２９５１，メルボルン　ビーチ，シー　ビュー　ストリート　２５８

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5K067 AA02　BB21　CC08　DD17　EE02　EE10　HH21　KK02

【要約の続き】

のルータ・ルックアップ・テーブルに類似の方法で制御機能により実行される。